الجامعة الأردنيـــــة
كلية الدراسات العليا

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نموذج رقم (١٨)
اقرار والتزام بالمعايير الأخلاقية والأمانة العلمية
وقوانين الجامعة الأردنية وأنظمتها وتعليماتها
لطلبة الماجستير

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عنوان الرسالة: ....
Electrical Demand Side Management Under Restructuring
....

اعلن بأنني قد التزمت بقوانين الجامعة الأردنية وأنظمتها وتعليماتها وقراراتها السارية المفعول المتعلقة باعداد رسائل الماجستير عندما قمت شخصيا" باعداد رسالتي وذلك بما ينسجم مع الأمانة العلمية وكافة المعايير الأخلاقية المتعارف عليها في كتابة الرسائل العلمية. كما أنني أعلن بأن رسالتي هذه غير منقولة أو مستلة من رسائل أو كتب أو أبحاث أو أي منشورات علمية تم نشرها أو تخزينها في أي وسيلة اعلامية، وتأسيسا" على ما تقدم فانني أتحمل المسؤولية بأنواعها كافة فيما لو تبين غير ذلك بما فيه حق مجلس العمداء في الجامعة الأردنية بالغاء قرار منحي الدرجة العلمية التي حصلت عليها وسحب شهادة التخرج مني بعد صدورها دون أن يكون لي أي حق في التظلم أو الاعتراض أو الطعن بأي صورة كانت في القرار الصادر عن مجلس العمداء بهذا الصدد.

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ELECTRICAL DEMAND SIDE MANAGEMENT UNDER RESTRUCTURING

By

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This Thesis was Submitted in Partial Fulfillment of the Requirements for the

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COMMITTEE DECISION

This Thesis/Dissertation (Electrical Demand Side Management under Restructuring) was successfully Defended and Approved on 20/3/2011

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LIST OF ABBREVIATIONS

Abbreviation	Terminology
AES	Amman East Power Plant
BOO	Building ,Ownership, Operation
CDA	Conditional Demand Analysis
CEGCO	Central Electricity Generating Company
DOS	Department of Statistics
DSM	Demand Side Management
EDCO	Electricity Distribution Company
EE	Energy Efficiency
EPC	Energy Performance Contracting
ERC	Electricity Regulatory Commission
ESCO	Energy Service Companies
GDP	Gross Domestic Product
IDECO	Irbid District Electricity Company
IPP	Independent Power Producer
IRP	Integrated Resource Planning
ISO	Independent System Operator
JEPCO	Jordan Electric Power Company
LM	Load Management
MEMR	Ministry of Energy and Mineral Resources

NEPCO	National Electric Power Company
NN	Neural Network
QEPCO	Qatraneh Electric Power Company
RJEPS	Restructured Jordanian Electric Power System
SEPGCO	Samra Electric Power Generating Company
SSM	Supply Side Management
SWH	Solar Water Heating
TOU	Time-Of-Use

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ELECTRICAL DEMAND SIDE MANAGEMENT UNDER RESTRUCTURING

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ABSTRACT

Restructured electric power systems are becoming over-stressed due to shrinking reserve margins and financial risks of bulk expansion. Demand-Side Management is one of the strategies used to reduce these effects. Consequently, in order to explore the potential of using load shifting of the Jordanian residential electrical energy consumption as a Demand Side Management technique, a survey was conducted to determine the consumption pattern of household appliances. The results showed that there is a feasibility for the shifting of morning and evening peaks by at least 60MW and 49 MW respectively.

CHAPTER 1

INTRODUCTION

Countries around the world have restructured their power systems in order to stimulate private investment, increase operation and management efficiencies, and lower the cost of power generation. These countries are unbundling vertically integrated utilities into distinct generation, transmission, distribution and retail supply companies; introducing commercial management principles to government owned monopolies (Vine, et al., 2003).

Changing electricity markets in the developing and the developed countries face several challenges, largely due to the uncertainties in the load growth, higher investments required in capacity addition, declining fuel sources, high fuel prices and its associated environmental costs. These have set the platform for Power Utilities to seek alternate strategies such as investment into renewable energy technologies and work towards optimizing demand side consumption, which is usually called Demand Side Management (DSM).

Since restructuring has changed the relationship between utilities and clients, utilities should be prepared to face the new market conditions. DSM can be seen as a new resource both to successful retail markets and efficient system operation.

In general electrical energy consumption of the residential sector accounts for 16–50% of that consumed by all sectors. This significant consumption level warrants a detailed understanding of the end-use consumption of the residential sector to find the potential of adopting DSM measures (Swan and Ugursal, 2009).

The successful design and implementation of Electrical Demand Side Management techniques in the residential sector depend mainly on the detailed information about end-use consumption of household equipments. However obtaining detailed and accurate data on energy systems is challenging, particularly for complex and developing systems such as those describing the household energy needs (Cross and Gaunt, 2003).

1.1 Thesis Objective and Contributions

Jordan has restructured its power system by applying a single buyer model, and due to the high increasing rate of energy demand and the limited energy resources of Jordan, DSM is one of alternate strategies to mitigate the energy problems in Jordan. Also the Jordanian residential sector accounts for more than 40 % of the total electricity consumption (NEPCO, 2010). Hence the objective of this thesis is to determine the end-use consumption of some household's equipments over various intervals during the day and then to estimate the amount of load shifting.

1.2 Thesis Structure

The thesis contains four chapters including the introduction as follows:

Chapter two reviews the literature survey and theoretical background.

Chapter three presents the developed work: survey, collected data through survey, data analysis, methodology and model used and results obtained.

Chapter four includes the conclusions

CHAPTER 2

LITERATURE SURVEY AND THEORITICAL BACKGROUND

2.1 Electric Power Industry: Deregulation and Restructuring

During the last decades governments worldwide have been seeking to liberalize their power sectors, to reduce costs associated with the generation, transmission and distribution of power, promote innovation, improve productivity and enhance international competitiveness. Before that there were vertically-integrated companies operating under a monopoly franchise i.e. it performs all of the functions involved to produce and sell electric power for a specified area of the country. In other way it is responsible for generating, transmission and distribution of electric power.

The Main advantage of the traditionally regulated industry is the coordination of all the functions required to provide a highly reliable electrical supply. Whereas the disadvantage is the absence of competitive market which creates losses in efficiency and economic incentives that are important factors in a market-based economy.

In 1990 the United Kingdom privatized its vertically integrated electricity industry. After that with the European Directive 96/92, since 19th February 1997, the deregulation of electricity sector has started in Europe. For indication of this directive, all consumers of all state members should have the freedom to choose their electricity supplier. California in the other side of the world followed this liberalization step in 1996.

Deregulated systems still maintain transmission as natural monopoly because deregulation of transmission grid will make the system complex. The Independent System Operator (ISO) which is a separate entity operates the regional transmission

grid. It is responsible to make certain that the electric grid stays up and running and that it is able to transmit power from the generating plants selling it to the people buying it (Shahidehpour, et al., 2002).

The reform process of the electricity industry results in one, or typically more, of the following changes in the power sector: commercialization, privatization, unbundling, and the introduction of competition. It is important to recognize that most reforms occur over a period of years, and thus tend to occur in stages across a continuum of policy and structural changes (Vine, et al., 2003):

2.1.1 Commercialization:

Commercialization involves introducing commercial objectives into the management and operation of a state-owned (public) utility. Most countries view commercialization as an intermediate step toward privatization and other reforms. Under commercialization, the utility becomes a business entity subject to the same tax laws, prices and accounting rules as other private sector companies. Commercialization often imposes separate cost accounting for generation, transmission, and distribution services. Cost recovery is improved by changing tariff structures to better reflect the true costs of service to various customer classes, by upgrading revenue collection through more effective metering and billing practices, and by differentiating tariffs for a given customer class according to the time of day at which power is demanded.

2.1.2 Privatization:

Privatization means transferring publicly owned power sector assets to private ownership. A country may decide to allow private development of some, or all, of the new power sector infrastructure. Many countries' electricity sectors have traditionally

been publicly owned and often dominated by a central planning philosophy. Governments tend to view electricity as a public service. Regulatory institutions are established to protect the public interest and balance social objectives with the financial health of the utility. Under privatization, some countries are opening generation to private investment, further privatizing transmission and distribution, and even restructuring the sector to introduce competition and independent regulation. However, privatization can be undertaken while maintaining the franchise monopoly structure, as was the case in the United States for many decades.

2.1.3 Unbundling:

When the electricity sector is "unbundled", vertically integrated utilities are separated into legally and functionally distinct companies providing generation, transmission, distribution and retail services. Implementation of unbundling varies between countries. In some unbundled power sectors, the distribution subsectors are horizontally divided according to geographic franchises. Some countries have separated the physical aspect of distributing electricity to final customers from retail services (marketing, bill collection, customer information, energy efficiency and load management, etc.) while others have kept them within the same entity. Unbundling can be combined with privatization, and/or can be undertaken for a government-owned utility without moving to privatization.

2.1.4 Competition:

Although the "wires" portion of the electricity sector (transmission and distribution services) is generally considered a natural monopoly, competition may be introduced into the system for selling power to the grid (wholesale competition) and providing electricity to end use customers (retail competition).

Regarding the restructuring process it is important to point out:

- Competition can be introduced with or without unbundling and with or without changing the ownership structure of the utility sector (Vine, et al., 2003).
- Competition does not necessarily mean deregulation (Vine, et al., 2003).
- Liberalization does not mean privatization, but cash-starved governments often equate the two (Charles River Associates**,** 2005).
- While privatization may provide a way out for many developing and transition countries, it is premature to think of privatization without ensuring that electricity is efficiently priced (Charles River Associates**,** 2005).

2.2 Demand Side Management

The electric utility planning process has traditionally consisted of first estimating the future demand for electricity, then finding the best set of supply- side options to meet the demand. Due to the oil crisis in the mid-1970, the planners were wondering why demand is treated as fixed quantity? The result of this question was a revolution termed Demand Side Management (DSM).

2.2.1 What is DSM?

DSM consists of electric utilities planning, implementing, and monitoring of activities designed to encourage consumers to modify their levels and patterns of electricity consumption (Gellings and Chamberlin, 1993). These activities are performed to benefit utilities, consumers, and society.

Load Management (LM), Energy Efficiency (EE), and Electrification are programs falling Under the DSM umbrella. Energy efficiency is aiming to reduce the overall energy consumption as shown in figure (2.1). And sometimes it is referred to as energy conservation. Technically speaking, the two are different since the level of energy service (e.g., the level of lighting in a room) is preserved under energy efficiency but declines under energy conservation. EE involves technology measures that produce the same or better levels of energy services while using less energy. These technologies are generally long-lasting and save energy across all times when the end-use equipment is in operation. Also Depending on the timing of equipment use, energy-efficiency measures can also produce significant reductions in peak demand.

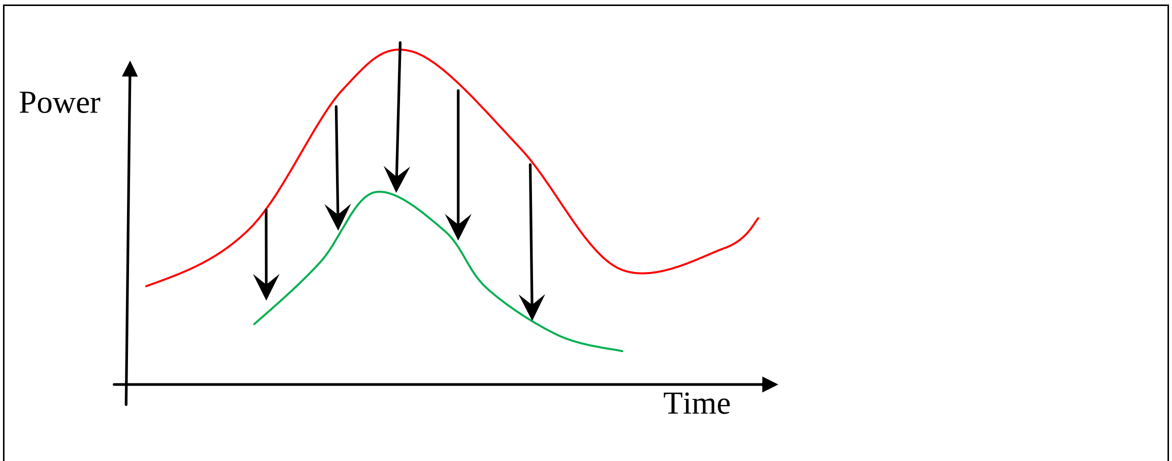

Figure (2.1) Energy efficiency

As shown in figure (2.2) electrification involves load building over all hours and it is often associated with customer retention programs from the perspective of the utility. It can also involve the development of new markets and customers strategic electrification, where the latter means expanding the uses of electricity to achieve other objectives such as economic development e.g. programs that encourage cost effective electrical technologies that operate primarily during periods of low electricity demand (Chuang and Gellings, 2008).

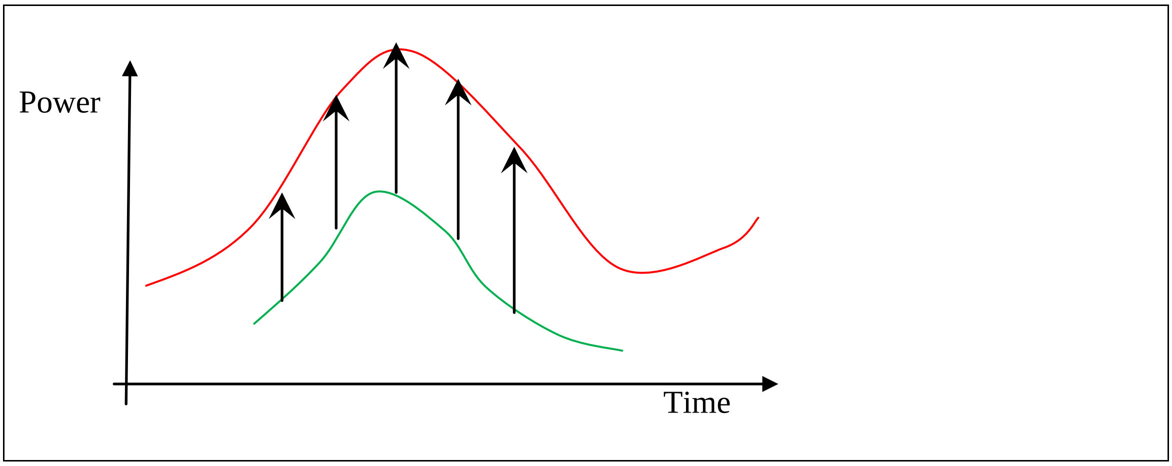

Figure (2.2) Electrification

LM programs include measures which aim to make better use of the existing installed electrical capacity or to defer or obviate the need for new capacity. Therefore the primary objective of load management is to modify the load profile, to redistribute energy demand to spread it more evenly throughout the day, not to save energy. Hence LM is increasingly being replaced by the term Demand Response. As shown in figure (2.3), Peak clipping, valley filling and load shifting are classified as load management objectives (Chuang and Gellings, 2008).

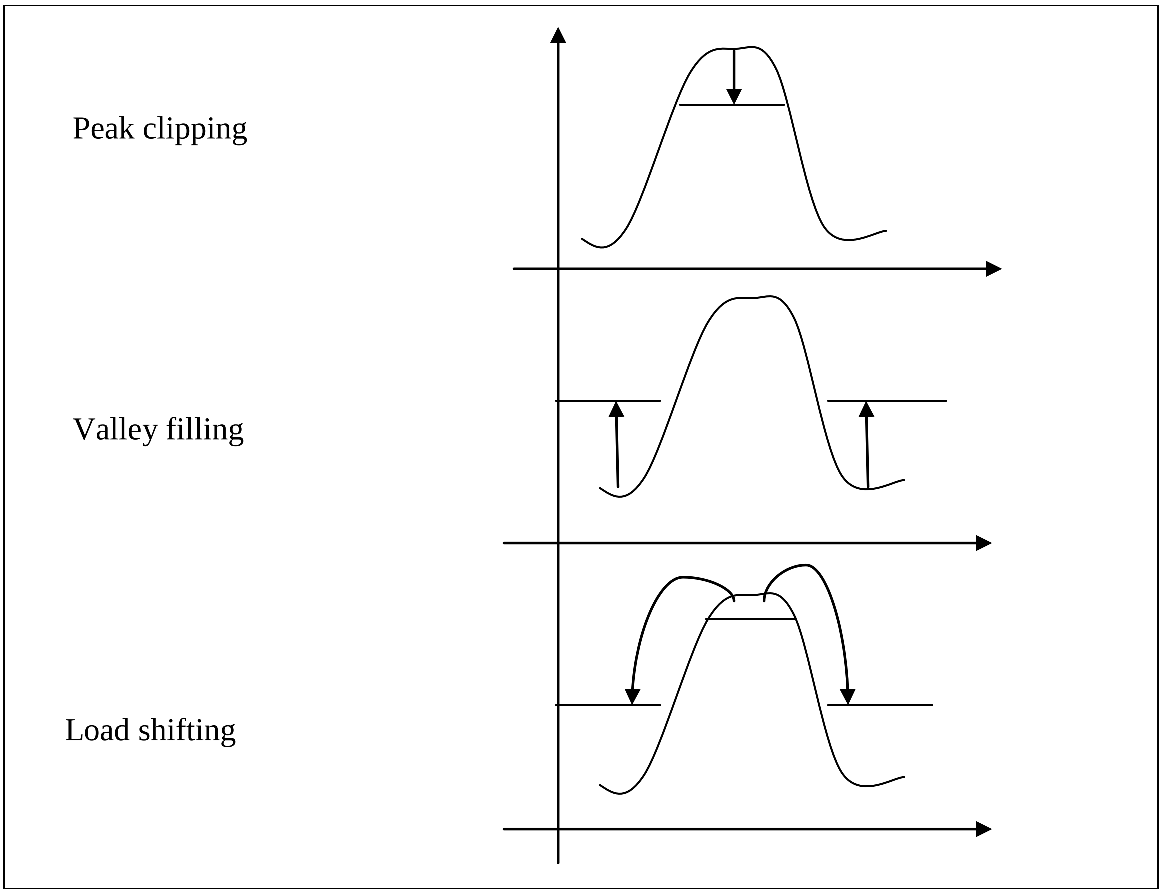

Figure (2.3) Load management objectives

2.2.2 Why DSM is adopted?

Using DSM techniques will enable us to influence customers demand pattern and when this method is used in a proper way it will play an essential role in reducing electrical system emergencies, avoiding blackouts, increasing system reliability, reducing dependency on expensive imports, reducing high energy prices, reducing air pollution and providing relief to the power grid and generation plants.

To see the benefits of DSM programs hereafter two examples of DSM success (Hu, et al., 2005):

1. South Africa’s largest electric utility, Eskom, expected the avoiding of 7,300 MW of new capacity through the use of energy efficiency and load management, even while adding 5,000,000 new customers by 2007.
2. Total electricity consumption in the Southwest, the fastest-growing region in the United States, could be cut 33 percent by 2020 with the accelerated use of presently available energy efficiency technologies at an average cost of $0.02 per kilowatt-hour (kWh).

2.2.3 DSM alternatives

According to Talukdar and Gellings, (1986) the Load management alternatives are:

1. End – use equipment control: this is one of the most active areas of technology development. The majority of the work is in the residential sector, because residential loads have the poorest load-shapes and for most utilities constitute the largest load sector. A few utilities with large commercial or industrial loads have targeted this sector for their initial load management programs. Techniques that control air conditioning, water heating, pumps, space heating and multiple loads are included in this category.
2. Energy storage: one of first energy conservation and load management techniques identified was energy storage (primarily thermal energy storage). It was recognized that a large number of possibilities existed to provide both energy savings and demand reduction through energy storage measures. Energy storage techniques operate equipment to provide storage during off-peak periods and utilize that stored energy during peak periods. Ice storage, heat storage and storage water heaters are techniques included in this category.

3. Customer DSM promotions: customer DSM promotions are planned activities sponsored by the utility to motivate customers to carry out actions to achieve DSM activities.
4. Performance improvement: the development of electric equipment and processes that provide improved performance in the form of more efficient operation or utilization of energy. These types of programs are usually considered in the conservation category rather than as load management alternatives.
5. Incentives rates: electric power rate design and incentive programs constitute a powerful class of DSM tools. They are perhaps the broadest type of DSM techniques in use. Most DSM programs employ some form of incentive to encourage participation by customers. Interruptible, load control contracts and incentives are techniques included in this category.
6. Utility equipment control: in most cases when people think of load management alternatives they think in terms of control over the customers equipments. But there are also a few controls on the utility equipment that should be considered as a comprehensive program. These are voltage reduction, feeder control and power factor control.
7. Dispersed generation: Dispersed generation as load management alternative can come in many forms. Alternatives such as wind generators, solar thermal, solar cells, standby generators, cogeneration and similar types of independent generation sources can be implemented or coordinated by utilities to meet DSM objectives.

The last two alternatives are considered as Supply Side Management (SSM) alternatives since the separating limit between the DSM and SSM is the KWh meter in our houses. Due to the higher cost of SSM techniques, DSM is the dominant.

2.3 Residential DSM

The residential sector is substantial consumer of energy in every country. Therefore most of countries start with the residential sector in their DSM programs. The first step in adopting successful DSM measures is obtaining the data required for the residential sector or to be more specific the household end-use consumption pattern. For the residential sector obtaining detailed and accurate data on energy systems is challenging, particularly for complex and developing systems such as those describing the household energy needs (Cross and Gaunt, 2003). This is according to (Swan and Ugursal, 2009) because the residential sector is largely an undefined energy sink due to the following reasons:

1. The sector encompasses a wide variety of structure sizes, geometries and thermal envelope materials.
2. Occupant behavior varies widely and can impact energy consumption by as much as 100% for a given dwelling.
3. Privacy issues limit the successful collection or distribution of energy data related to individual households.
4. Detailed sub-metering of household end-uses has prohibitive cost.

The methods for obtaining the required data are either using meters or conducting a survey, the first one which is called monitoring studies takes two approaches; Monitoring equipment that can be used to record the consumption of individual appliances or of collections of appliances. This will provide accurate consumption data on individual appliances and the results are of sufficient details to make energy efficiency recommendations. The second approach is to monitor the whole house

electricity consumption at a high resolution (Firth, et al., 2008). But this method is very expensive so it is used in the developed countries and on small scale studies. The references (Firth, et al., 2008), (Stetson and Stark, 1988) and (Jardini, et al., 2000) are examples of this method.

The basic information collection method is by survey (Swan and Ugursal, 2009), since it is less expensive and can be made for larger sample size to reduce sampling errors. Survey method is used by Most of the studies done. The references (Yu and Wong, 1993), (Tatie´tse, et al., 2002) and (Lopes, et al., 2005) are examples of this method.

2.3.1 Modeling of residential energy consumption

Since the energy consumption characteristics of the residential sector are complex and inter-related, comprehensive models are needed to assess the technoeconomic impacts of adopting energy efficiency and renewable energy technologies suitable for residential applications (Swan and Ugursal, 2009).

Techniques used to model residential energy consumption can broadly be grouped into two categories, ‘‘top-down’’ and ‘‘bottom-up’’. The terminology is with reference to the hierarchal position of data inputs as compared to the housing sector as a whole. Top-down models utilize the estimate of total residential sector energy consumption and other pertinent variables to attribute the energy consumption to characteristics of the entire residential sector. In contrast, bottom-up models calculate the energy consumption of individual or groups of houses and then extrapolate these results to represent the region or nation.

Swan and Ugursal, (2009) provided an up-to date summary about the techniques used to model residential energy consumption:

1. Top-down approach: The top-down approach treats the residential sector as an energy sink and does not distinguish energy consumption due to individual end-uses. Variables which are commonly used by top-down models include macroeconomic indicators (Gross Domestic Product (GDP), employment rates, and price indices), climatic conditions, housing construction rates, and estimates of appliance ownership and number of units in the residential sector. Under this approach there are two types:
   a. Econometric models: these models are based primarily on price (of for example, energy and appliances) and income.
   b. Technological models: these models attribute the energy consumption to broad characteristics of the entire housing stock such as appliance ownership trends.

   In addition there are models which utilize techniques from both previous types.

2. Bottom – up approach: The bottom-up approach encompasses all models which use input data from a hierarchal level less than that of the sector as a whole. Models can account for the energy consumption of individual end-uses, individual houses, or groups of houses and are then extrapolated to represent the region or nation based on the representative weight of the modeled sample. This approach covers two types of models:

   a. Statistical methods: rely on historical information and types of regression analysis which are used to attribute dwelling energy consumption to

particular end-uses. Once the relationships between end-uses and energy consumption have been established, the model can be used to estimate the energy consumption of dwellings representative of the residential stock.

i. Regression: The regression technique uses regression analysis to determine the coefficients of the model corresponding to the input parameters. These models regress the aggregate dwelling energy consumption onto parameters or combinations of parameters which are expected to affect energy consumption.

ii. Conditional Demand Analysis (CDA): The CDA method performs regression based on the presence of end-use appliances. By regressing total dwelling energy consumption onto the list of owned appliances which are indicated as a binary or count variable, the determined coefficients represent the use level and rating.

iii. Neural Network (NN): The NN technique utilizes a simplified mathematical model based on the densely interconnected parallel structure of biological neural networks. The technique allows all end-uses to affect one another through a series of parallel ‘‘neurons’’. Each neuron has a bias term and array of coefficients that are multiplied by the value of the preceding layer’s neurons.

b. Engineering methods: explicitly account for the energy consumption of end-uses based on power ratings and use of equipment and systems and/or heat transfer and thermodynamic relationships.

i. Distributions: This technique utilizes distributions of appliance ownership and use with common appliance ratings to calculate the

energy consumption of each end-use. As end-uses are typically calculated separately, this technique does not account for interactions amongst end-uses. The product of appliance ownership, appliance use, appliance rating and the inverse of appliance efficiency results in the energy consumption. By aggregating the appliance consumptions on a regional or national scale the residential energy consumption is estimated.

ii. Archetypes: This technique is used to broadly classify the housing stock according to size, house type…etc. It is possible to develop archetype definitions for each major class of house and utilize these descriptions as the input data for energy modeling. The energy consumption estimates of modeled archetypes are scaled up to be representative of the regional or national housing stock by multiplying the results by the number of houses which fit the description of each archetype.

iii. Sample: This technique refers to the use of actual sample house data as the input information to the model. This allows for the capture of the wide variety of houses within the stock and can be used to identify regions with high-energy consumption. If the sample is representative of the regional or national housing stock, the stock energy consumption can be estimated by applying appropriate weightings to the results.

The same reference compares the three main approaches according to their advantages and disadvantages as shown in table (2.1).

Table (2.1) Positive and negative attributes of the three major residential energy modeling approaches.

	Top-down	Bottom-up statistical	Bottom-up engineering
Positive attributes	• Long term forecasting in the absence of any discontinuity • Inclusion of macroeconomic and socioeconomic effects • Simple input information • Encompasses trends	• Encompasses occupant behavior. • Determination of typical end-use energy contribution. • Inclusion of macroeconomic and socioeconomic effects • Uses billing data and simple survey information	• Model new technologies. • ‘‘Ground-up’’ energy estimation. • Determination of each end-use energy consumption by type, rating, etc. • Determination of end-use qualities based on simulation
Negative attributes	• Reliance on historical consumption Information • No explicit representation of end-uses. • Coarse analysis	• Reliance on historical consumption information • Large survey sample to exploit variety. • Multicollinearity.	• Assumption of occupant behavior and unspecified end-uses. • Detailed input information • Computationally intensive • No economic factors

2.4 DSM under restructuring

Electric industry restructuring may force regulators and policy makers to re-examine existing mechanisms for promoting load management and energy efficiency. In some cases, electric industry restructuring replaces the long-standing relationship between a single monopoly provider and protected customer franchise with a new set of relationships among retail electricity suppliers and customers who may now be free to choose suppliers (Vine, et al., 2003).

From the international experience Hu, et al., (2005) presented that restructuring has had the following effects on DSM:

- Policymaker, regulators, and utility focus on complex issues of power sector reform has often led to significant reductions in existing DSM programs.
- Separation of the grid from generation makes it more difficult for any one entity to see the full value of DSM. However, a single-buyer power supply company without the ability to pass all generation costs on to consumers retains the incentive to capture all of the generation, transmission, and distribution value of DSM.
- Separation of generation from transmission and distribution creates smaller companies with lower earnings and profit levels. This magnifies each utility's disincentive to invest in DSM.
- Markets deliver what they are designed to deliver and will only deliver energy efficiency if they are designed to do so. Markets can be designed to allow DSM to compete against power supply, but this is not often done.
- Many restructured markets have experienced much higher levels of price volatility than they had before restructuring. Where restructured markets have

exposed customers to this price volatility, customers have responded in a variety of ways, including with investment in load management options.

- In many countries e.g. U.S. states, industrial customers have been given preferential subsidized prices. Restructuring in some places has resulted in the loss of these subsidized prices.

These effects does not exist in all restructured systems, this because every country has its own special conditions. For example countries who adopted DSM before restructuring favored its adoption after restructuring, since they have an experience in that. However the main issues of DSM under restructuring that should be discussed are DSM implementation responsibility and funding DSM programs, which are interrelated issues.

It is obvious that a DSM will only be successful if both the actors who have to implement DSM measures and the actors who can choose to participate in it will benefit from doing so. According to Didden and D'haeseleer, (2003) and depending on table (2.2), Two categories of DSM frameworks can be distinguished:

1. Create an artificial DSM framework. A first type of DSM framework, that we shall refer to as an artificial framework, is obtained if an actor who does not have a primary incentive in saving energy, and is therefore in the 'loser'-column of table (2.2), gets the responsibility for implementing DSM. In order to retain a successful DSM framework, this actor must be incentivized by financial compensation, which means that he would 'artificially' be transferred from being a 'loser' to a 'winner'.

2. Create a natural DSM framework. The main idea of a natural DSM framework is to give the responsibility for energy efficiency to an entity that will have no financial losses if electricity consumption is reduced. This situation will be obtained, if an actor who is not in the 'loser' column of table (2.2) gets the responsibility.

Table (2.2) Balance, showing the actors whose prosperity will increase (winners) or decrease (losers) by an energy efficiency retrofit

Winners (+)	Losers (-)
Consumers	Manufacturers of conventional Equipment
Manufacturers of efficient equipment	Primary energy suppliers Utilities

Thus when regulators wish to promote demand-side management (DSM) activity by utilities, they must consider how to create incentives consistent with their objectives for DSM. But also International experience clearly demonstrates that DSM and energy efficiency in the electricity sector will only happen with clear, strong, and consistent government and regulatory leadership. Therefore it is most commonly, DSM programs are implemented by the Independent System Operator (ISO, which is sometimes called the Independent Market Operator).

There are three basic types of DSM incentive mechanisms: program cost recovery, lost revenue recovery, and rewards to shareholders based on DSM activity. Didden and D'haeseleer, (2003) suggests that For large energy consumers, energy efficiency should be through Energy Performance Contracting (EPC) which is an effective means to create a natural DSM framework, mostly carried out by Energy Service Companies (ESCO). The ESCO installs an energy efficient measure and takes full responsibility for its proper functioning. The ESCO is only paid for by the savings. Whereas For Smaller customers, e.g. residential, for whom the implementation of performance contracts is too expensive, should be subject to a public benefit charge.

In North America cost recovery and incentive provisions have been developed aimed at encouraging cost-effective demand-side management:

- Program cost recovery, referring to full recovery of utility expenditures for approved demand-side programs.
- LRAM or RevCap. LRAM refers to Lost Revenue Adjustment Mechanisms that make the utility as whole with regard to fixed costs lost through sales reductions from energy efficiency. RevCap refers to Revenue Caps, which provide for a maximum level of revenues during a multi-year period, during which revenues are decoupled from changes in sales.
- Shareholder incentive, referring to additional profits provided to the utility based on demonstrated DSM performance.

Hu, et al., (2005) suggested the following points to be considered when implementing DSM especially under restructuring:

- Make DSM a Service Obligation for Power Supply Companies: the most important policy to promote DSM is to establish who has the obligation to deliver DSM and energy efficiency services. International experience shows that barriers to DSM and energy efficiency are not overcome by power sector reform unless the issues are addressed directly. This means the responsibility to assess DSM potential and to design and implement programs must be assigned to a capable implementing entity. It also means that a mechanism to fund DSM must be established. Some countries have made DSM and energy efficiency delivery an obligation of the distribution utility. Others have assigned the responsibility to existing or newly established third-party entities. Experience shows that either approach can be successful. What is crucial is that the power sector reform process includes the assignment of DSM

responsibility to a utility or entity that has the funds and capacity to perform this critical role.

- Use Revenue-Capped Performance-Based Regulation: allowing the electric utility to recover its DSM costs is not enough to assure that the company will deliver DSM programs to the greatest extent possible. Unlike supply side investments, DSM, though cost-effective, poses a unique difficulty for the utility and regulator. The challenge has been to find ways to align the utility's financial interest with the public interest. In a number of countries, policy makers have turned to alternative ratemaking methods broadly referred to as "Performance-Based Regulation (PBR)," to solve the problem. Under the traditional cost-of-service methods of ratemaking, an electric company's revenues are determined by its level of sales. Almost any reduction in sales will result in reduced profits for the company. Thus, DSM investment may be much less costly than new power supply but, for the power supply company, adding supply means increased sales and increased revenue. Generally, the added revenue exceeds the added cost, so the grid utility's profits will increase when it chooses to increase supply. In contrast, the lower-cost DSM option reduces sales and revenues. Even if the cost of DSM is zero, the lower revenue means that the DSM option reduces the grid utility's profit. This is a very powerful disincentive for grid utility investment in DSM. Correcting this problem requires the adoption of tariff-setting methods that remove this financial disincentive to DSM. One approach, used successfully in Australia, the United Kingdom, South Africa and parts of the United States, is a form of PBR that sets a cap, or ceiling, on the revenues that a utility can retain.
- Standards and Rewards for DSM Performance: Correcting many of the DSM-related incentives in the tariff-setting process is a high near-term priority. In the longer term

it should be considered targeted incentives to reward superior DSM performance. Such incentives are also considered a form of “performance-based regulation,” but are distinct from PBRs of the type that apply to a utility’s overall revenues described in the previous section. Targeted rewards for meeting specified performance standards are often referred to as shareholder incentives, because any additional cash that the company receives because of these incentives goes directly to its bottom line, that is, to its earnings.

The effects of restructuring on DSM in Jordan are discussed in the next chapter (i.e. the developed work).

2.5Adopted Model:

In the developed work the bottom-up approach was adopted because it was found that it is the most suitable method for achieving the objective of the thesis (i.e. estimating peak load shifting based on collected data of actual use not on historical data as in the case of top-down approach).

2.6 Restructured Jordanian Electric Power System (RJEPS)

The Jordanian interconnected electrical power system consists of the generating power stations, 132 kV and 400 kV transmission network where this transmission network interconnects the power stations with the load centers among all the kingdom area. It also includes the 230 kV and 400 kV tie lines with Syria, 400 kV tie line with Egypt, 132 kV tie line with Palestine(it is still operated on 33 kV) and the distribution networks which serve about (99.9 %) of the total population in Jordan.

On September 1st, 1996 establishment of the National Electric Power Company (NEPCO) was officially announced as a legal and actual successor of Jordan Electricity

Authority. Before that, general electricity law no. 10 of 1996 was issued to replace the general electricity law no. 16 of 1986, in which Electricity Sector Regulatory Commission (ERC) was established accordingly. The new electricity law setting up a control body to regulate electricity sector and set basis and rules that govern relations among the sector corporations, issue licenses for power generating, transmitting and distributing, setting tariff, regulating and monitoring electricity service concerning credibility, safety procedures, environment and client protection. To continue the restructuring process, the government decided on October 4th, 1997 to restructure NEPCO by separating power generating activity from transmission and distribution activities; to be operated according to commercial rules through establishing an independent company per activity.

Facing the increasing growth in electrical loads requires setting up of new generation stations added to the RJEPS with the national transmission network, also it requires installing new and expanding several transmission substations operating in the RJEPS network, especially in the central areas of Jordan and substations to feed the new load centers that emerge and are hard to feed from the existing substations and in order to connect the new generation stations. During the period 2007-2011 new projects (combined cycles) on the electrical power generation based on IPP in a manner of Build , Own, Operate (BOO) are installed in two locations Amman East Power station (Almanakher) and Qatraneh Power station (Qatraneh). Also expansions in Samra Power station lead to two combined cycles and one simple cycle. During 2007 and 2008 the following RJEPS governmental companies CEGCO, IDECO and EDCO were privatized, hence just NEPCO and SEPGCO are still governmental companies.

The RJEPS consists of the following entities which are shown in figure (2.4):

- Ministry of Energy and Mineral Resources (MEMR)

- Electricity Regulatory Commission (ERC).
- National Electric Power Company (NEPCO).
- Generation Sector:
    1. Central Electricity Generating Company (CEGCO).
    2. Samra Electric Power Generating Company (SEPGCO).
    3. Amman East Power Plant (AES).
    4. Qatraneh Electric Power Company (QEPCO).
- Distribution sector:
    1. Jordan Electric Power Company (JEPCO).
    2. Irbid district Electricity Company (IDECO).
    3. Electricity Distribution Company (EDCO).

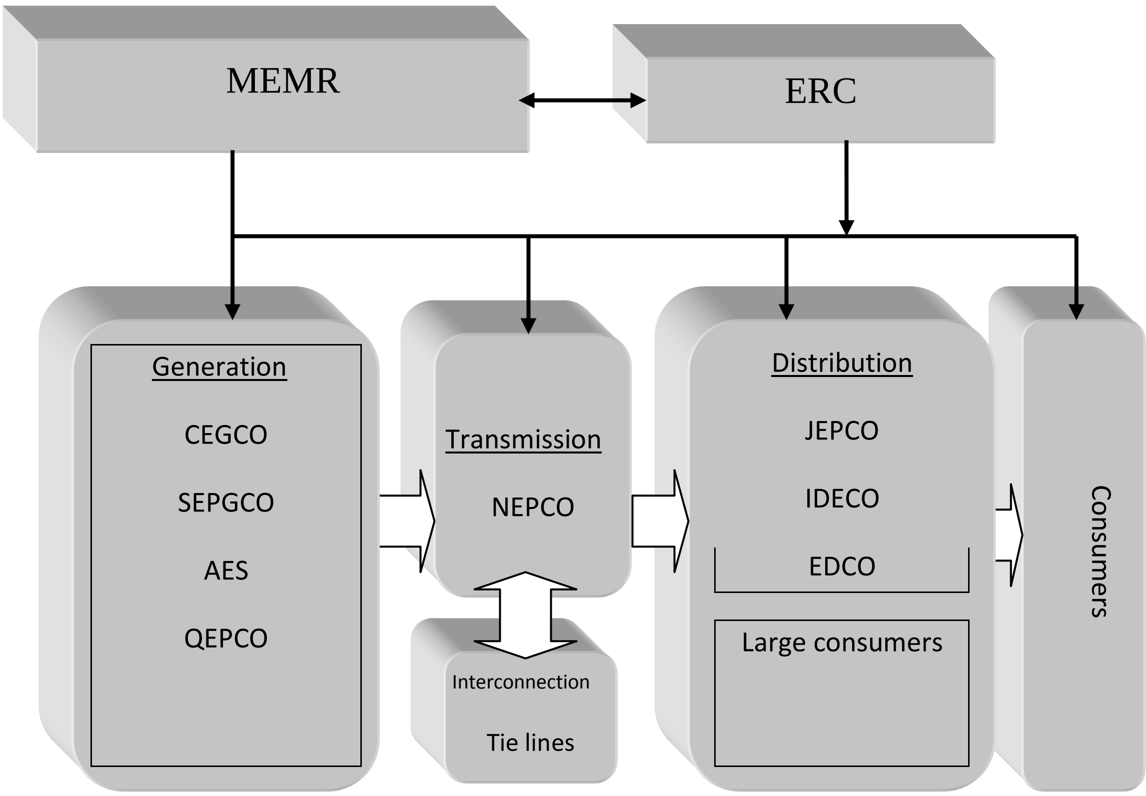

Figure (2.4) RJEPS

2.7 DSM in Jordan

Jordan is facing an increasing growth in electrical energy demands especially in the residential sector which is the highest consumption sector among other sectors as shown in figure(2.5) and figure(2.6) (NEPCO, 2010).

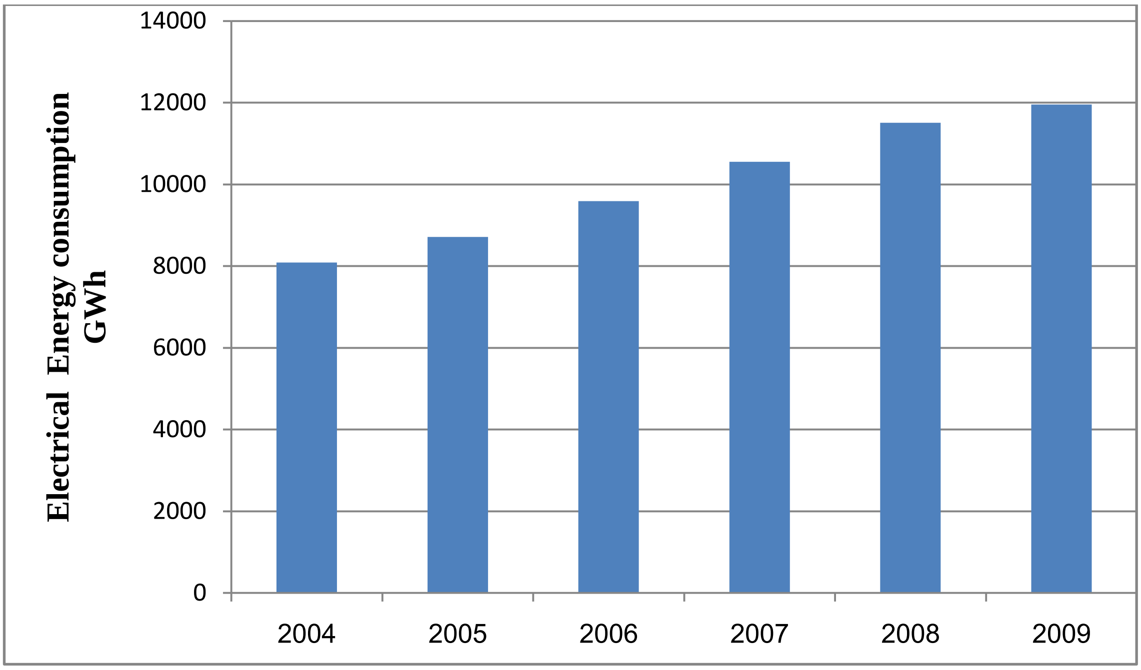

Figure (2.5) Electrical energy consumption in Jordan.

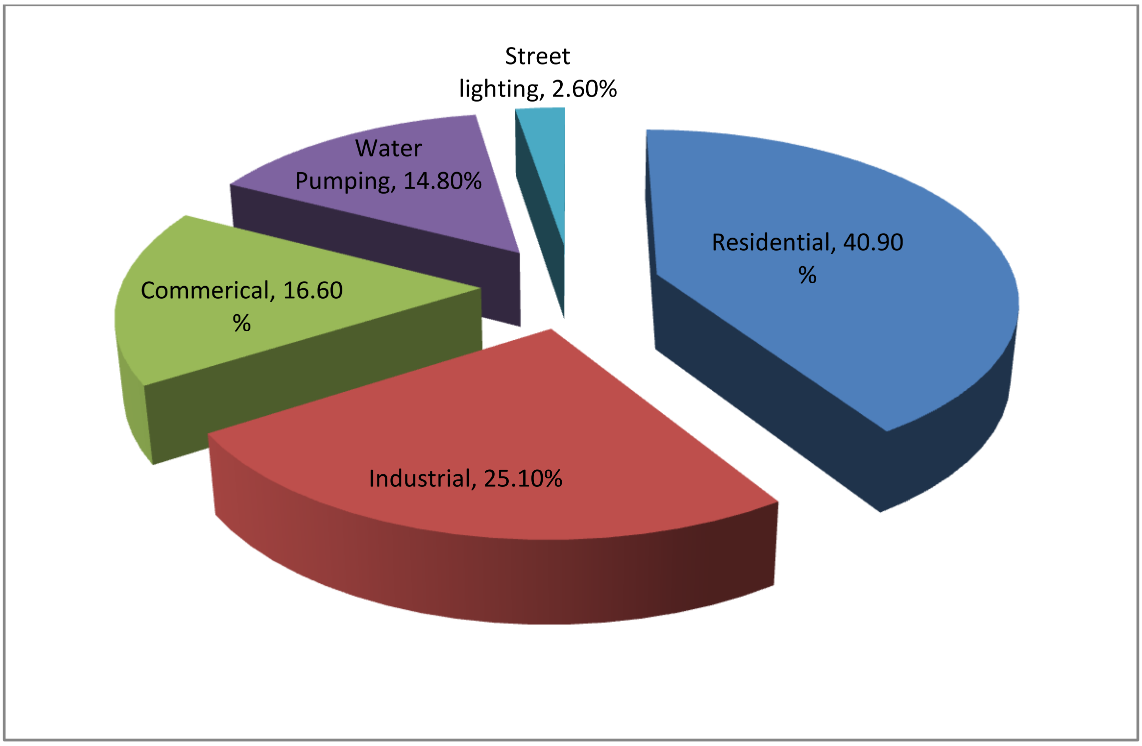

Figure (2.6) Breakdown of Jordan electrical energy consumption

Unlike neighboring countries in the Middle East, Jordan is a non-oil producing country and is nearly fully dependent on imported oil from neighboring countries which consumes a large portion of its budget. Therefore, the search for alternative energy sources and the efficient energy management have become critical issues in Jordan.

In 1989 Jordan Electricity Authority implemented low cost Load Research Programs aiming to have a good and complete data about the load characteristics of different consumption sectors. This considered the one of the first steps of DSM in Jordan. Then consequent studies were conducted by Jordan Electricity Authority and then by its legal successor NEPCO.

By reviewing NEPCO records, the following were observed:

- Regarding water pumping sector a comprehensive survey was carried out for 1000 pumping station and water wells all over JORDAN. It was found that there is an opportunity to shift about 24 MW in summer time and 36 MW in winter time out of system peak.
- In the industrial sector a survey was conducted to find the possibility of implementing the time-of-use tariff (TOU) in small industries. The result of this survey was a recommendation to apply the TOU tariff on small industries with installed load more than 100 kW, but TOU tariff is applied only on the industries more than 200 kW. Another survey for 135 medium industries was carried out. The sample represents the different types of industry in Jordan. The results showed a good potential for reducing the peak load within the industrial sector. The load reduction was estimated to be about 22 MW could be shifted out of the system peak.
- With regard to the commercial sector, a survey was carried out for a sample of 18 hotels and 7 banks and the results were used in tariff structure.
- A project for street lighting efficiency improvement was carried out to replace the old lamps with energy efficient lamps.
- Energy Conservation awareness campaign carried out in 1998 and 2002. 300,000 bulletins were distributed to residential and commercial consumers with electricity bills.
- In April 2006 technical and economic studies were completed for improving the Efficient consumption of energy of 20 different establishment in the industrial and commercial sector. The results of these studies pointed to the possibility of saving around 20% of the energy consumption in these establishments.

- The Efficient Energy Label project has been initiated and implemented in order to provide the citizen with the necessary information on the optimal appliances and equipment's consumption of energy. Also in order to encourage the citizens to buy energy efficient appliances and equipments for conservation of energy, government has decided to approve exemption of these appliances and equipments from customs duties and this is already done for compact fluorescent lamps and solar water heaters.

2.8 Residential end-use consumption in Jordan

To determine the residential energy flow and efficiency, the energy end use quantities of a typical Jordanian household should be known. Such detailed data and information are not available in Jordan not only for the residential sector but also for most of Jordanian sectors (Al-Ghandoor, et al., 2008). There are few studies about the residential end-use consumption in Jordan, two pertinent comprehensive surveys have been conducted by MEMR, The first one conducted in 1986 (MEMR, 1987) and the other in 1996 (MEMR, 1997).

In the last years of the last century unpublished small scale studies have been carried out on residential sector by NEPCO using load research monitors, the purpose of these studies was to use these collected data in tariff structure.

During the second half of 2003 The Department of Statistics (DOS) conducted the Multi-purpose Household Survey which includes an in depth analysis of some topics such as; population, housing units characteristics, education, economic participation and home economy. And in the home economy part the structure of the household wealth section talked about the percentage of owning some home appliances which is used by some studies in the residential end-use energy consumption calculation (DOS, 2004).

In 2007 DOS conducted a survey in cooperating with ERC about using the electricity in space heating and conditioning (DOS, 2008).

Few papers were published regarding the end-use electricity consumption of residential sector, as well as most of these papers even the new ones depended on somehow on the Results of the MEMR 1996 survey, (Momani, et al., 2009), (Akash and Mohsen, 1999) and (Kablan, et al., 1999) are examples of these papers.

Al-Ghandoor (2008) presented an analysis of the energy and exergy utilization of the Jordanian urban residential sector by considering the flows of energy and exergy through the main end uses and applications in Jordanian households and to achieve this purpose, a survey covering 200 households was conducted and energy consumption data were gathered.

Al-Ghandoor, et al., (2009) "in open literature, no study was found trying to evaluate and project potential energy savings in the Jordanian residential sector". Therefore in his paper (Al-Ghandoor, et al., 2009) he provided a forecasting model of fuel and electricity consumptions during next decade and evaluated impacts of introducing high efficiency lightings and solar water heating (SWH) systems on future fuel and electricity consumptions and associated reduction in CO_2 emissions.

2.9 Conclusion

This chapter presented previous works regarding local and international DSM such as: The essence and benefits of DSM, restructuring of power systems and its effects on DSM, Electrical energy consumption in residential sector and its modeling techniques, and restructuring of Jordan electrical power system and DSM in Jordan.

It is obvious that DSM is one of the techniques that can be used to reduce the energy problems before and after power systems restructuring. But unfortunately it is not utilized efficiently in Jordan especially in the residential sector, and few studies published about this sector. The first step in determining the feasibility of adopting DSM in the residential sector is to obtain relevant data about the end-use consumption patterns and particularly the time of use of home appliances to determine the portion they share in the peak value which is essential data for load management techniques which is the object of this thesis taking into account that none of the studies done before in the residential sector in Jordan had covered the time of use, i.e. peak or off-peak loads, whereas this issue is covered in this study.

CHAPTER 3

DEVELOPED WORK

3.1 Introduction

The successful design and implementation of Electrical Demand Side Management techniques in the residential sector depend mainly on the detailed information about end-use consumption of house hold equipments.

The problem in engineering effective Load Management in the residential sector is the lack of adequate information regarding the hourly use profiles of end use devices (Thomae, et al., 1981).

The residential sector in Jordan consumed more than 40% of the total electricity consumption in 2009, and this percentage increases yearly (NEPCO, 2010). Hence the detailed study of the residential consumption pattern is required to start with the residential DSM measures design and implementation.

3.2 Residential End-use consumption

The electricity consumption of a household is determined by the electric power consumed by each appliance and the amount of time each appliance is in use.

Firth, et al. (2008) divided the home appliances into four categories according to their pattern of use: continuous appliances; standby appliances; cold appliances; and active appliances. Continuous appliances draw a continuous constant amount of power. Standby appliances, in particular consumer electronic equipment such as televisions, have three basic modes of operation: in use; on standby; or switched off. Standby use

occurs when an appliance is not in use but is still consuming power. Appliances can be on standby even when they appear to be switched off and the only certain way to prevent them drawing power is to disconnect their power supply. Cold appliances, such as fridges and freezers, are in continuous use however they do not draw constant amount of power. Instead their power consumption cycles between zero and a set power level which is under thermostatic control. Active appliances are those which are actively switched on or off by the householders and are clearly either in use or not in use. Active appliances have no standby mode and when switched off their power consumption is zero. Examples of active appliances include lights, kettles and washing machines.

The data required to construct end-use consumption pattern of Jordan's residential sector were obtained using two methods: Data logger meters and a survey.

3.2.1 Data logger meters

The load management section in NEPCO installed a data logger meter for recording fifteen minute average electrical power consumption of a distribution feeder connected to 236 dwellings at Umm- Alsummaq area at the capital Amman over a three month (March, April and May) monitoring period.

The area was selected for two reasons: first it is a representative sample of a typical Jordanian household and secondly the feeder is feeding only residential consumers. Figures (3.1), (3.2) and (3.3) show the obtained average daily load curve of the feeder for each month. The curves show that: i) The residential morning peak of Holidays is larger than that of working days. ii) The evening peak is the dominant due to lighting load.

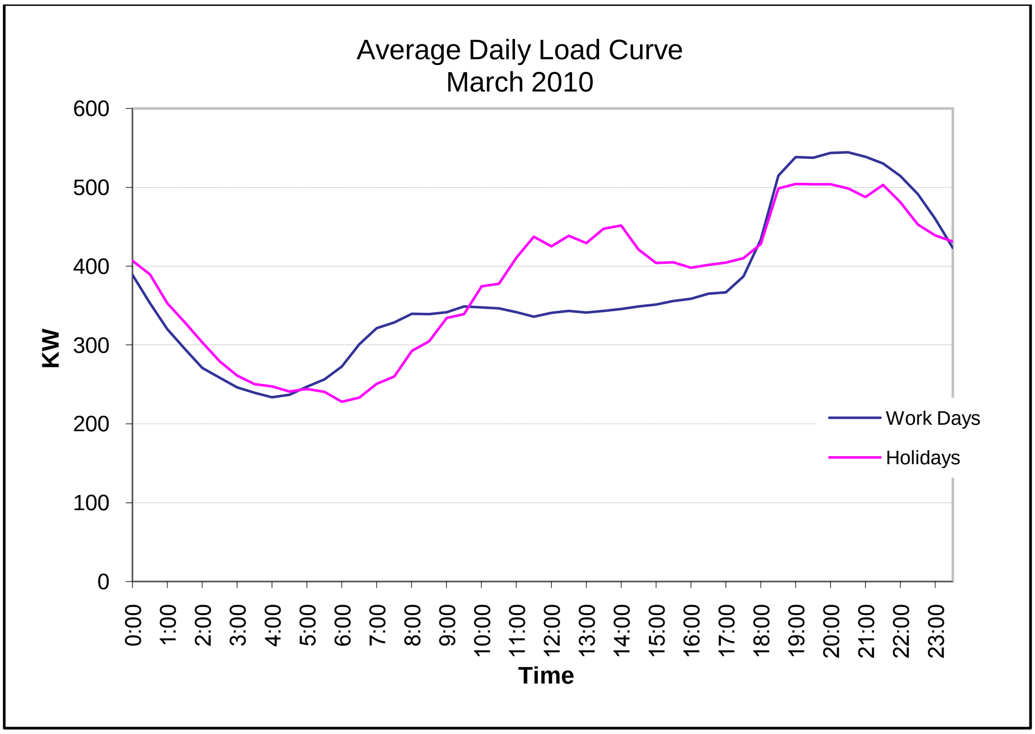

Fig (3.1) Average daily load curve at umm-Alsummaq area, March 2010

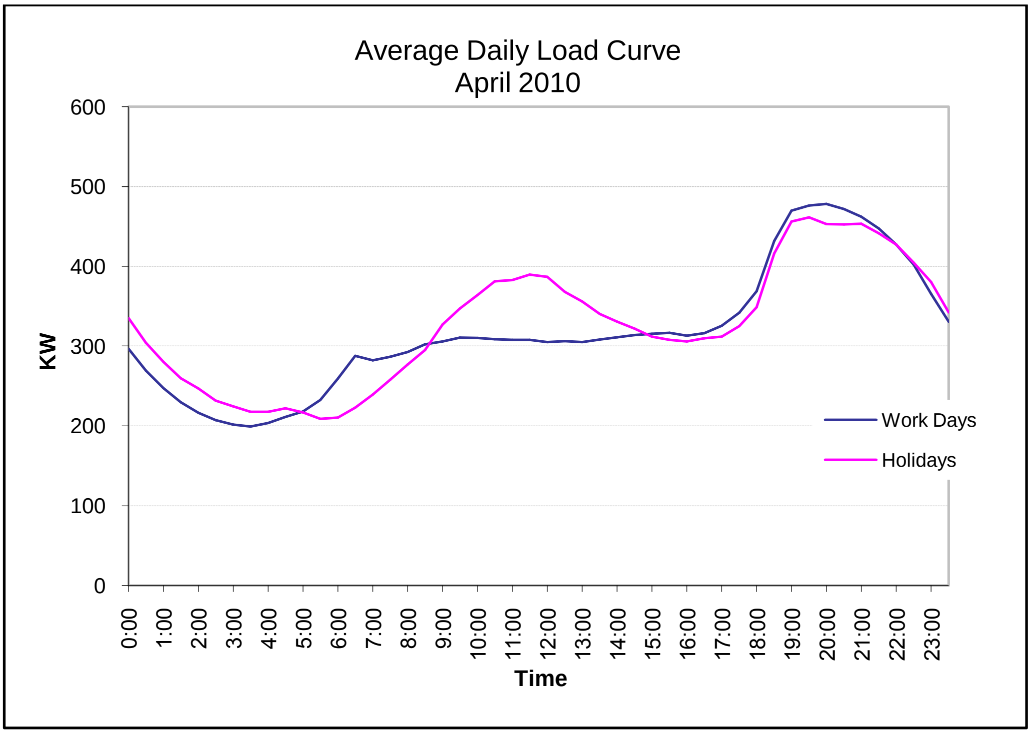

Fig (3.2) Average daily load curve at umm-Alsummaq area, April 2010

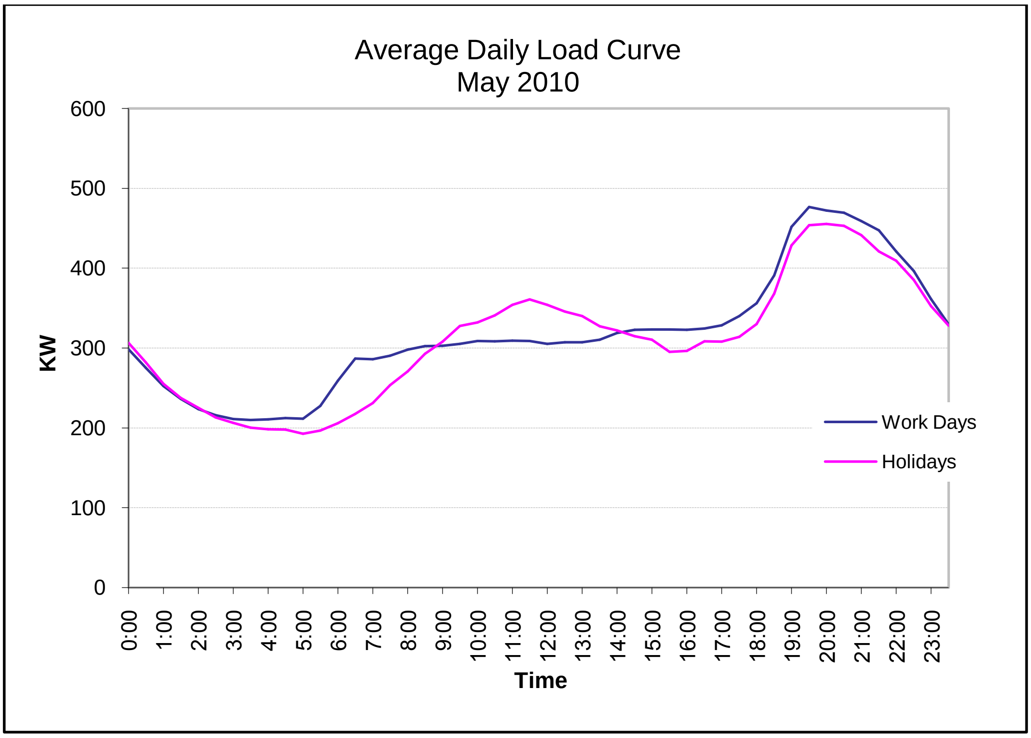

Fig (3.3) Average daily load curve at umm-Alsummaq area, May 2010

3.2.2 Residential End-use consumption survey

The only comprehensive survey had been done more than 13 years ago (MEMR, 1997); many things had changed since that time, as well as previous surveys (DOS, 2004), (DOS, 2008) and (Al-Ghandoor, et al., 2008) didn't take in account the time of using appliances, this is very important factor to break down the residential daily load profile. Also one of the most important lessons of the past 30 years of world energy policy is that analyzing how people use energy, and how energy use changes over time, can yield important policy insights (Brown and Koomey, 2003).

Since the collection of such data on a national scale is a costly process a survey was conducted by the author during the months of August and September 2010 using a designed questionnaire, as shown in appendices A and B, of a representative sample of 391 households at different locations and living standards in Jordan. The survey was

completed by engineering students at the University of Jordan, Hashemite University, Yarmouk University, Jordan University for Science and Technology, Balqa'a Applied University, Philadelphia University, Tafila Applied University, and Mu'tah University. The students participated in the survey volunteered to complete a detailed questionnaire about the electrical power consumption in their households. 500 questionnaires were distributed, 419 questionnaires were received and only 391 questionnaires were accepted to be included in the analysis, the others were rejected due to the incompleteness or inconsistency of the data.

According to (Montgomery and Runger, 2007) if the sample mean $\bar{X}$ used as an estimate of the population mean μ, we can be 100(1-α)% confident that the error$|\bar{X}$ - μ $|$ will not exceed aspecified amount E when the sample size is:

$$n = \left(\frac{Z_{\alpha/2}\sigma}{E}\right)^2 \quad \text{.. (3.1)}$$

Where:

n: sample size.

(1-α) : confidence coefficient for example 95%, 99%.

σ : standard deviation of the population.

$Z_{\alpha/2}$: The upper 100α/2 percentage point of the standard normal distribution.

And for large sample size i.e. n > 40 then replacing σ by the sample standard deviation S has little effect on the distribution of Z,then the confidence interval of the mean with confidence level of approximately 100(1-α)% will be:

$$\bar{X} - Z_{\alpha/2}\frac{s}{\sqrt{n}} \leq \mu \leq \bar{X} + Z_{\alpha/2}\frac{s}{\sqrt{n}} \text{ .... (3.2)}$$

The confidence level tells us how sure we can be. It is expressed as a percentage and represents how often the true percentage of the population who would pick an answer lies within the confidence interval. The 95% confidence level means you can be 95% certain; the 99% confidence level means you can be 99% certain. Most researchers use the 95% confidence level. Whereas the confidence interval (also called margin of error) is the plus-or-minus figure usually reported in newspaper or television opinion poll results. For example, if we use a confidence interval of 4 and 47% percent of our sample picks an answer we can be "sure" that if we had asked the question of the entire relevant population between 43% (47-4) and 51% (47+4) would have picked that answer. When we put the confidence level and the confidence interval together, we can say that we are 95% sure that the true percentage of the population is between 43% and 51%.

The previous equation will be used in the questionnaire results analysis as shown in appendix C. For our survey the confidence level used is 95% i.e. α=0.05 which the used level in such surveys and it is used by DOS previous surveys. A confidence interval 5 is selected. Then using these values for a population of 1098000 households having considerable amount of energy consumption (provided by the Electricity sector Regulatory Commission (ERC)) then the minimum required sample size is 384. Also (Krejcie and Morgan, 1970) greatly simplified size decision by providing a table that ensures a good decision model and according to this table for population size larger than 1000 000 the required sample size should be larger than 384. Roscoe (1975) also proposed that sample size between 30 and 500 are appropriate for most researches.

Consequently in the developed work the obtained sample of 391 households is considered sufficient and representative for the residential sector in Jordan.

The questionnaire was designed to elicit information from consumers under the following categories:

1. The amount of monthly electrical KWh consumption in summer and winter as it is recorded in the utility bills (i.e. January and July electrical bills).
2. Ownership of appliances: The proportion of households where a given appliance is available and the number of appliances owned.
3. Electrical power rating of the used appliances.
4. Usage-patterns for appliances: This describes the average estimated daily usage duration in the winter and summer months and the most frequent time of use of the day where the day is divided into five unequal periods depending on the morning and evening peaks periods (i.e. 11am - 2pm & 5pm – 9pm) which are determined by NEPCO depending on the electrical power system average daily load curve.

3.3 Questionnaire analysis and results

3.3.1 Monthly electrical energy consumption:

The monthly consumption of the respondents of the questionnaire has shown that the average winter monthly consumption is larger than that in summer months as shown in table (3.1). This justifies what happened during winter seasons of the last three years when the system winter load became larger than that of summer because of the increase in using electricity for space heating due to the sharp increase of oil prices. Figure (3.4) shows the monthly consumption of the sample compared with that provided by ERC for

the total population. From the figure it can be concluded that although they have the same normal distribution trend but there is a shift on the average value between them, which means the sample average is slightly larger than that of the population.

Table (3.1) Average Monthly consumption during summer and winter seasons

Season	Summer	Winter
Average monthly consumption KWh	457	501

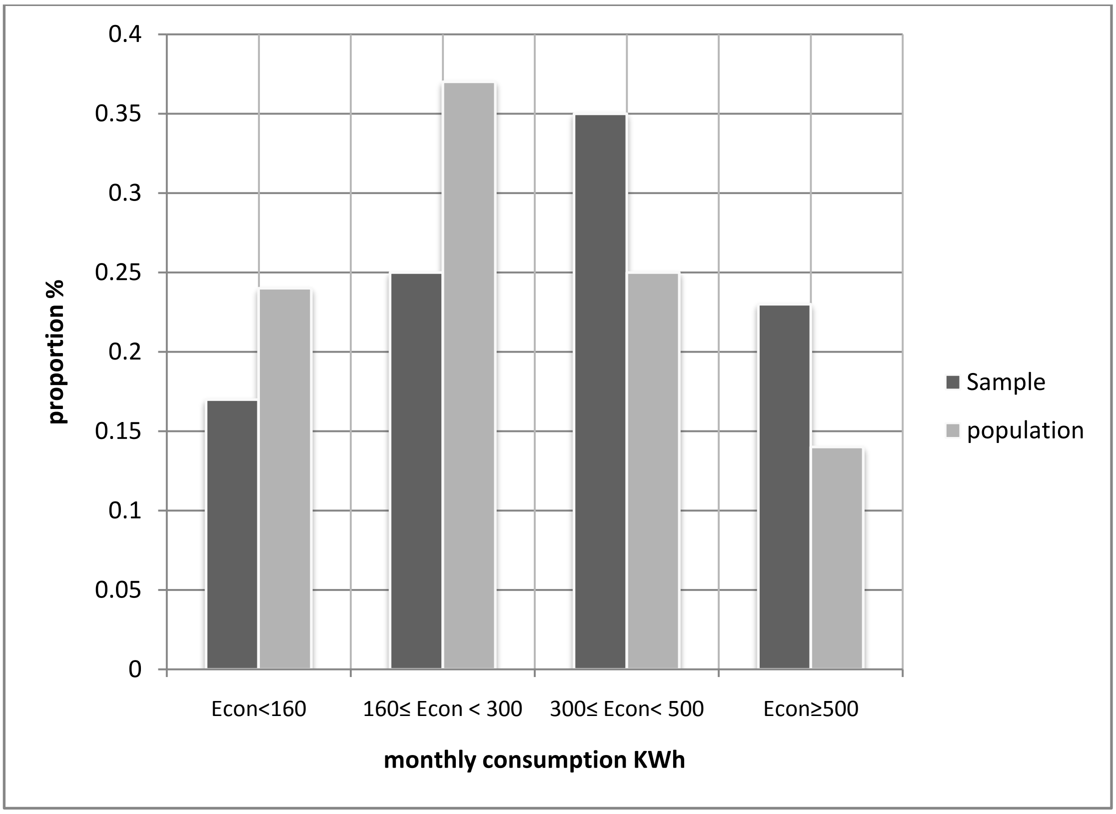

Figure (3.4) monthly consumption of the obtained sample compared with the actual figures

3.3.2 Home appliances ownership:

Table (3.2) shows the proportion of the sample owning the specified appliances and the ownership levels (it is also called penetration level) of that appliances.

Figure (3.5) shows a comparison between the obtained results and those of (MEMR, 1997) regarding the ownership proportion.

Table (3.2) Ownership proportion and ownership level of the sample.

Home appliances		Ownership proportion %	Ownership level appliance/ house
Laundry	Ordinary Washing Machine	21.48	0.22
	Semi Automatic Washing Machine	15.35	0.15
	Full Automatic Washing Machine	66.5	0.67
	Dryer	6.65	0.07
Air conditioning	Fan (normal or ceiling)	89.51	1.9
	Air Conditioner	26.6	0.32
Space Heating	Electrical Heater	61.38	0.82
	Oil Radiator	3.58	0.03
Water heating	Electrical water heater	62.4	0.71
Cooking	Electric Cooker	4.09	0.04
	Electric Oven	9.46	0.1
	Microwave Oven	57.54	0.58
Lighting	Fluorescent Lamps	80.31	6.01
	Incandescent Lamps	57.29	4.3
	Energy Saving Lamps	46.8	3.84
	Floodlight	4.09	0.07
Other Appliances	Colored T.V & Receiver	99.49	1.25
	Iron	85.17	0.93
	Vacuum cleaner	74.42	0.79
	Dish washer	8.7	0.09
	Water pump	29.16	0.31
	Personal computer	77.75	1.1
	Blender mixer	65.47	0.77
	Hair dryer	65.47	0.79
Food Reservation	Refrigerator less than 10 cuft	4.09	0.05
	Refrigerator (10-13) cuft	9.21	0.09
	Refrigerator (14-16) cuft	46.04	0.49
	Refrigerator larger than 16 cuft	41.43	0.42
	Freezer	18.67	0.2
	Water cooler	42.46	0.45

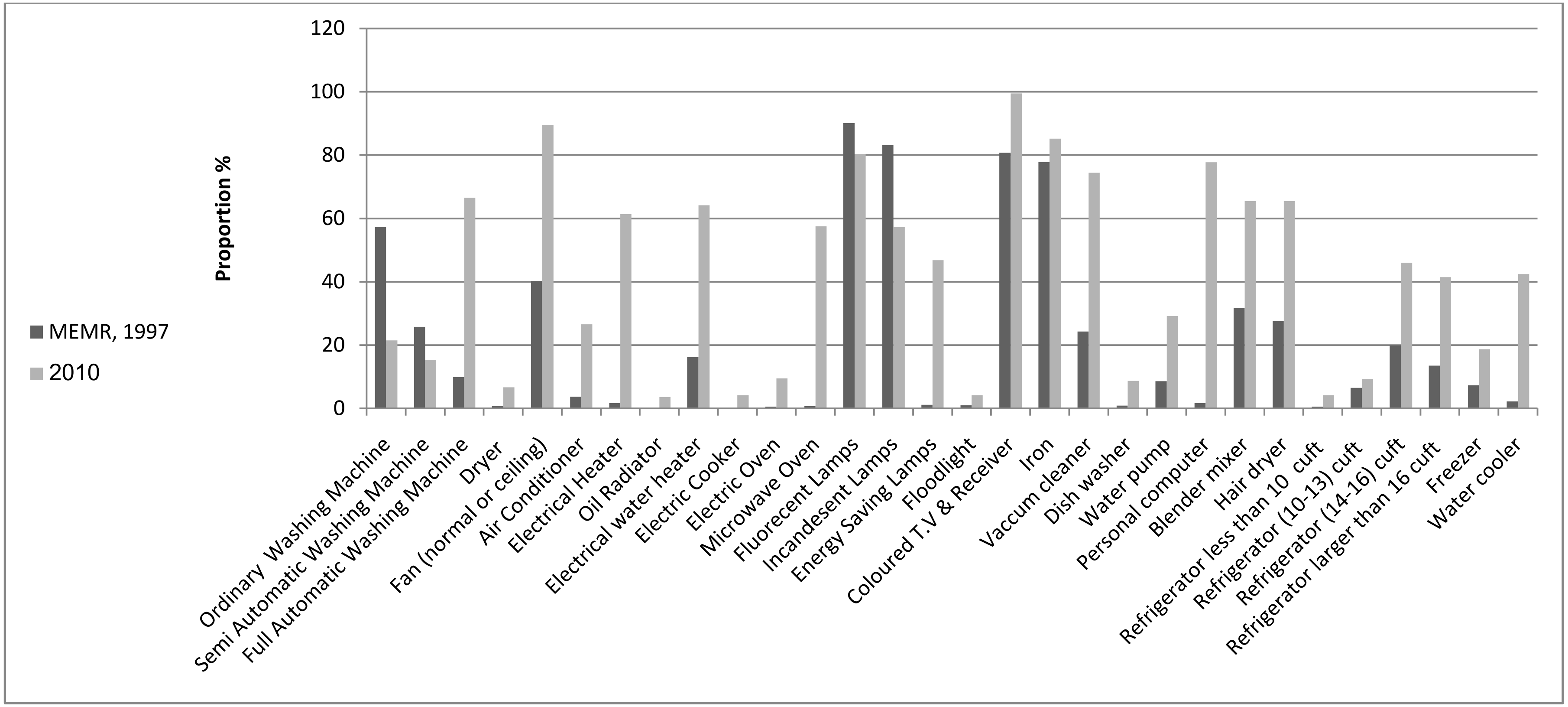

Figure (3.5) comparison between the obtained results and those of (MEMR, 1997)

The comparison shows a large increase in the usage of most electrical appliances, except the ordinary and semi automatic washing machines; because consumers prefer using full automatic washing machines. Also there is a decrease in using fluorescent and incandescent lamps due to the increase in using energy saving lamps.

Figure(3.6) shows a comparison between the obtained results and those of (DOS,2004) survey regarding the proportion of using some appliances that DOS survey exposed to them in their survey since it is not a comprehensive survey regarding the household appliances. It can be observed that there is a natural increase rate in using appliances, except for personal computers and microwave ovens due to the decreasing rate of their prices and the need for personal computers nowadays.

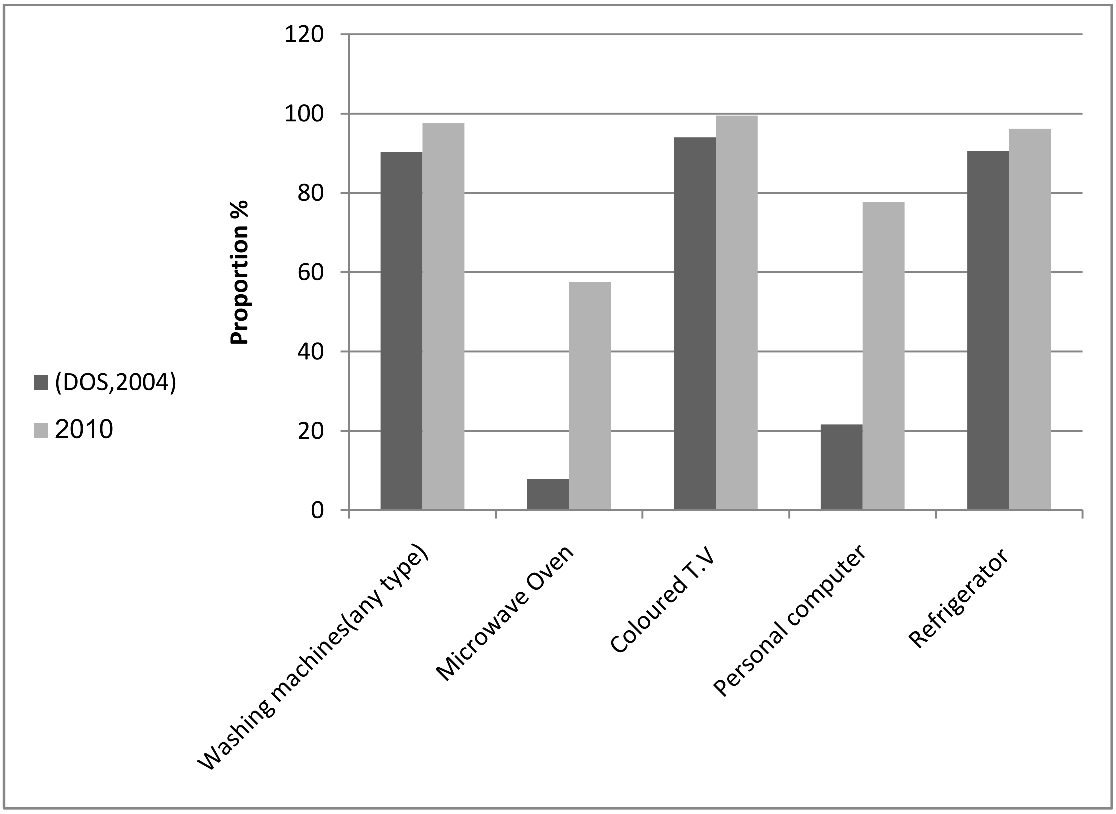

Figure (3.6) comparison between the obtained results and those of (DOS, 2004)

The results obtained from this survey are very close to those obtained from the survey carried out by DOS in 2007 Regarding the space heating and air conditioning appliances as shown in figure (3.7). The rapid increase in the air conditioners is clearly noticed and this is justified since this survey conducted during and after the hot summer period this year which forced many consumers to own air conditioners. Also these Air conditioners are used increasingly in space heating during winter due to the sharp increase in oil prices.

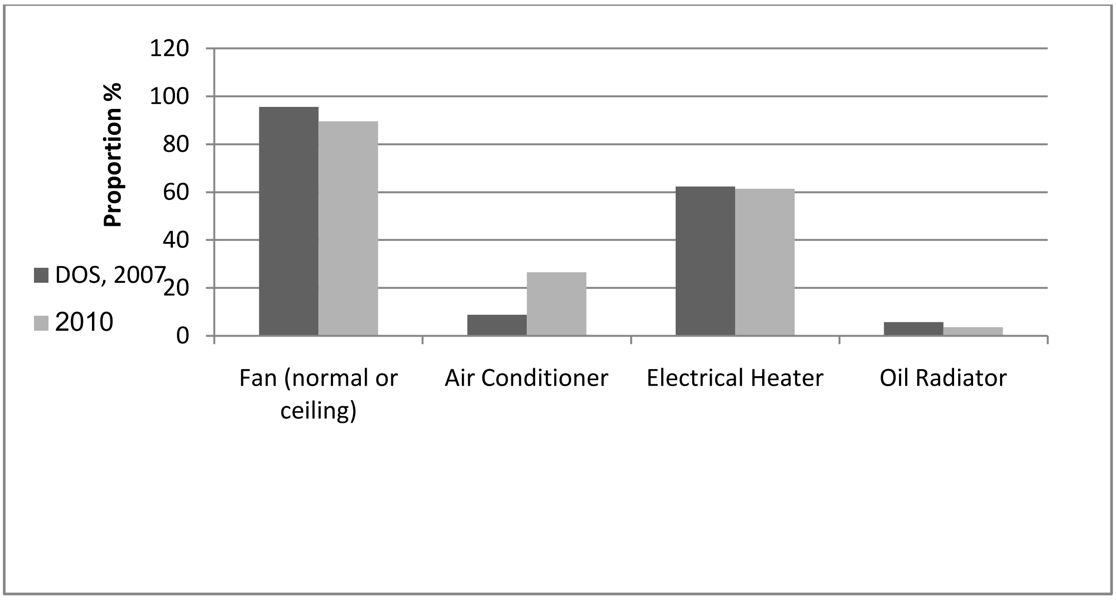

Figure (3.7) comparison between the obtained results and those of (DOS, 2008)

The last survey done regarding the energy consumption of home appliances is that done by Al-Ghandoor, et al. (2008). Figure (3.8) shows a comparison between the results of ownership level of this survey compared with that of the obtained results. It can be noticed some differences between the results. This is due to the different sample sizes taken 391 and 200 and because there is more than two years between the two surveys, but in general they are comparable.

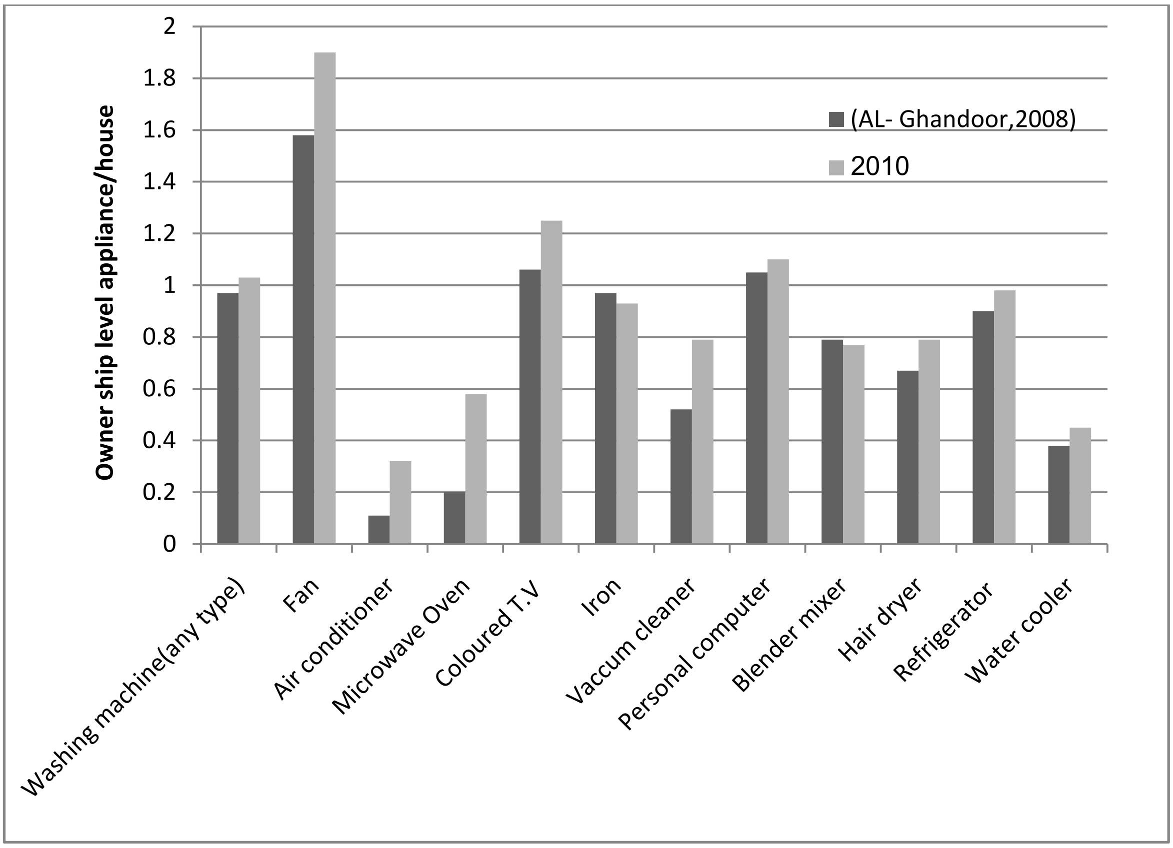

Figure (3.8) comparison between the obtained results and those of (Al-Ghandoor, et al., 2008)

3.3.3. Usage-patterns of appliances:

Previous surveys (MEMR, 1997), (DOS, 2008) and (Al-Ghandoor, et al., 2008) studied the average estimated daily usage duration but none of them took into account the frequency of use per the day. However in the survey of the developed work both of these were taken into account. Table (3.3) shows the obtained results of the average estimated daily usage duration in summer and winter.

Table (3.3) the average estimated daily usage duration in summer and winter in hours

Home appliances		Average daily utilization time in hours	
		Summer	Winter
Laundry	Ordinary Washing Machine	0.34	0.27
	Semi Automatic Washing Machine	0.39	0.33
	Full Automatic Washing Machine	0.68	0.64
	Dryer	0.11	0.28
Air conditioning	Fan (normal or ceiling)	8.5	0
	Air Conditioner	7.35	5.43
Space Heating	Electrical Heater	0	6.1
	Oil Radiator	0	5.55
Water heating	Electrical water heater	1.45	4.1
Cooking	Electric Cooker	1.63	1.63
	Electric Oven	0.92	0.89
	Microwave Oven	0.3	0.27
Lighting	Fluorescent Lamps	7.08	7.81
	Incandescent Lamps	5.85	6.14
	Energy Saving Lamps	6.85	7.51
	Floodlight	5.31	4.7
Other Appliances	Colored T.V & Receiver	11.23	11.35
	Iron	0.27	0.22
	Vacuum cleaner	0.3	0.25
	Dish washer	0.97	0.93
	Water pump	0.48	0.22
	Personal computer	6.1	6.23
	Blender mixer	0.15	0.12
	Hair dryer	0.31	0.2

In order to convert these daily results to annual results and then compare them with previous obtained results (Al-Ghandoor, et al., 2008) the following assumptions were made: i) There are equal number of hot and cold days per year and this taken number is 110 days. This number is only used for air conditioning and space heating appliances. ii) For other appliances, the daily average time is assumed for all days during the year. The calculated annual results are shown in table (3.4) and the comparison is shown in figure (3.9), from which it can be concluded that the results are close to each other except for washing machine, fan, iron and blender mixer.

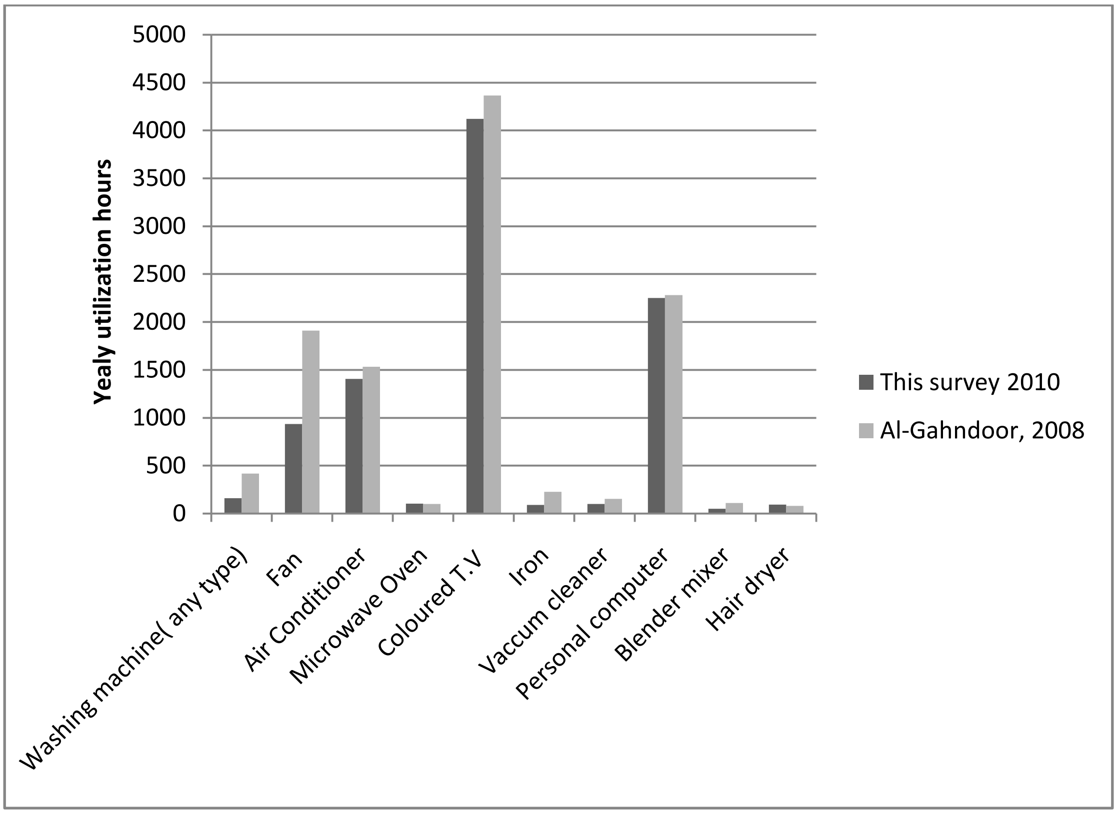

Figure (3.9) comparison between the obtained Annual utilization time results and those of (Al-Ghandoor, et al., 2008)

Table (3.4) Annual utilization time in hours

Home appliances		Annual utilization time in hours	
		This survey	Al Ghandoor 2008
Laundry	Ordinary Washing Machine	111.325	416
	Semi Automatic Washing Machine	131.4	
	Full Automatic Washing Machine	240.9	
	Dryer	71.175	*
Air conditioning	Fan (normal or ceiling)	935	1911
	Air Conditioner	1405.8	1533
Space Heating	Electrical Heater	671	*
	Oil Radiator	610.5	*
Water heating	Electrical water heater	1012.875	*
Cooking	Electric Cooker	594.95	*
	Electric Oven	330.325	*
	Microwave Oven	104.025	99
Lighting	Fluorescent Lamps	2717.425	*
	Incandescent Lamps	2188.175	*
	Energy Saving Lamps	2620.7	*
	Floodlight	1826.825	*
Other Appliances	Colored T.V & Receiver	4120.85	4365
	Iron	89.425	226
	Vacuum cleaner	100.375	153
	Dish washer	346.75	*
	Water pump	127.75	*
	Personal computer	2250.225	2281
	Blender mixer	49.275	110
	Hair dryer	93.075	80

* The utilization time of these appliances were not included in (AL-Ghandoor, et al.,2008).

With regard to the utilization time of cold appliances such as fridges, freezers and water coolers were not included in the questionnaire because they are in continuous use and they do not draw constant amount of power, So that respondents can't provide information about their use.

The other part of usage-patterns is the most frequent time of use during the day. As mentioned before the day is divided into five unequal intervals depending on the morning and evening peaks of the Jordanian daily load curve. Although the time of water feeding is somehow affecting the time of using washing machines in Jordan but it is neglected in this survey. Table (3.5) shows percentage of operating intervals for every appliance. Figure (3.10) shows bar chart for these intervals and percentages of every appliance.

Table (3.5) Percentage of day intervals of appliances use

Appliances	The percentage of operating intervals %				
	7am - 11am	11am - 2pm *	2pm - 5pm	5pm - 9pm **	after 9pm
Ordinary Washing Machine	66.96	17.86	5.36	7.14	2.68
Semi Automatic Washing Machine	75.34	16.44	0	4.11	4.11
Full Automatic Washing Machine	28.57	32.8	22.75	10.58	5.29
Dryer	25.64	38.46	20.51	10.26	5.13
Fan (normal or ceiling)	7.7	22.04	27.14	23.48	19.63
Air Conditioner	4.78	15.65	35.22	23.91	20.43
Heater	16.32	11.28	15.97	31.08	25.35
Oil Radiator	8.7	8.7	17.39	34.78	30.43
Electrical water	36.17	11.58	11.09	20.26	20.9
Electric Cooker	25	36.11	16.67	13.89	8.33
Electric Oven	24.14	41.38	13.79	10.34	10.34
Microwave Oven	19.54	12.85	41.39	22.62	3.6
Fluorescent Lamps	5.7	6.61	13.47	39.77	34.46
Incandescent Lamps	4.75	6.11	18.33	40.05	30.77
Energy Saving Lamps	1.67	5.56	15	42.78	35
Floodlight	0	0	8	28	64
Colored T.V & Receiver	10.14	17.74	22.73	26.34	23.04
Iron	27.18	29.13	16.18	16.5	11
Vacuum cleaner	57.23	23.12	10.98	5.78	2.89
Dish washer	16	21.33	38.67	16	8
Water pump	40.74	19.14	12.35	22.84	4.94
Personal computer	7.59	13.87	25.84	32.99	19.71
Blender mixer	10.6	48.39	33.18	6.91	0.92
Hair dryer	23.53	20.26	27.45	23.53	5.23

* Morning peak period   ** Evening peak period

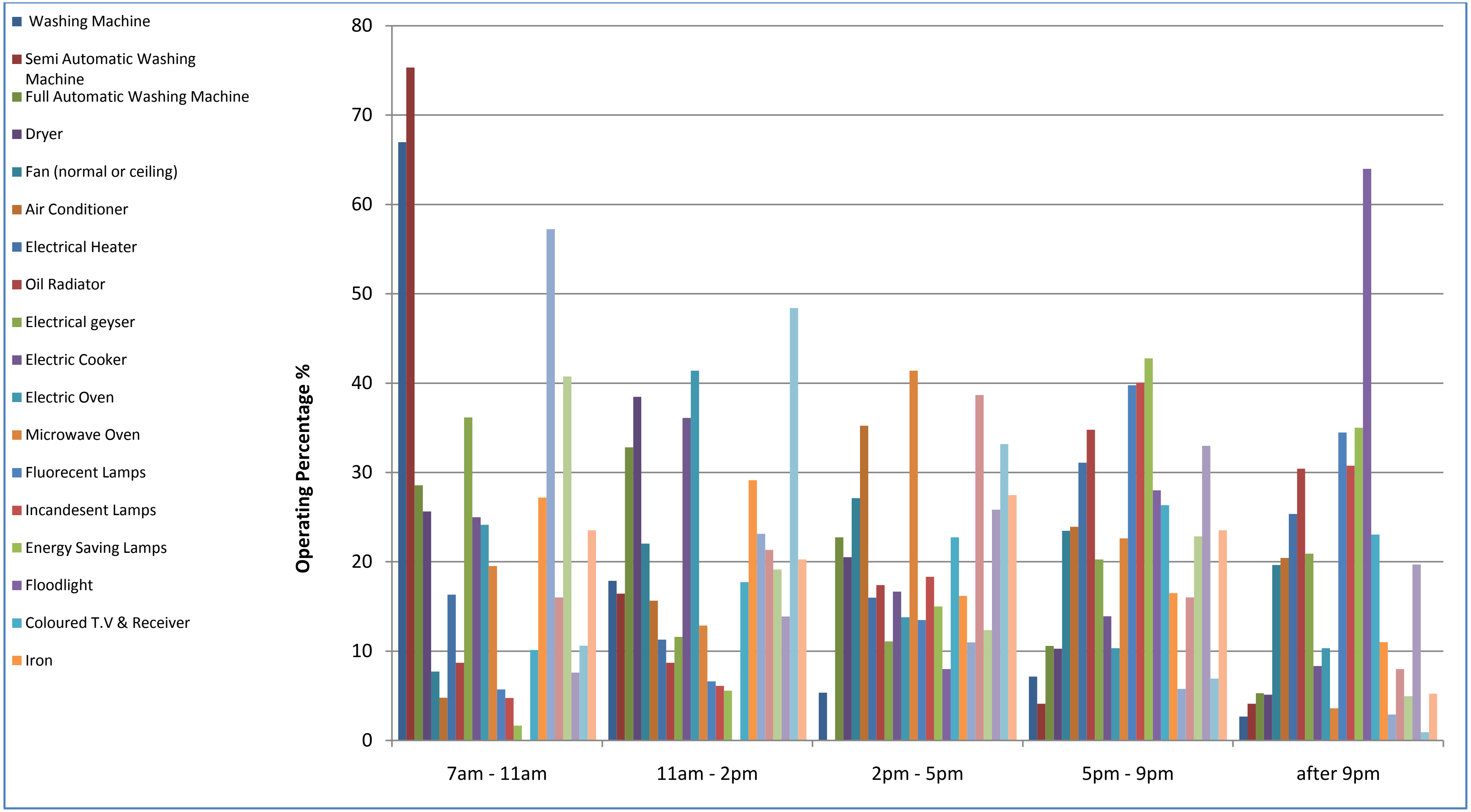

Figure (3.10) percentages of the time intervals of using appliances

Figures (3.11 - 3.16) show the bar chart for each related group of appliances.

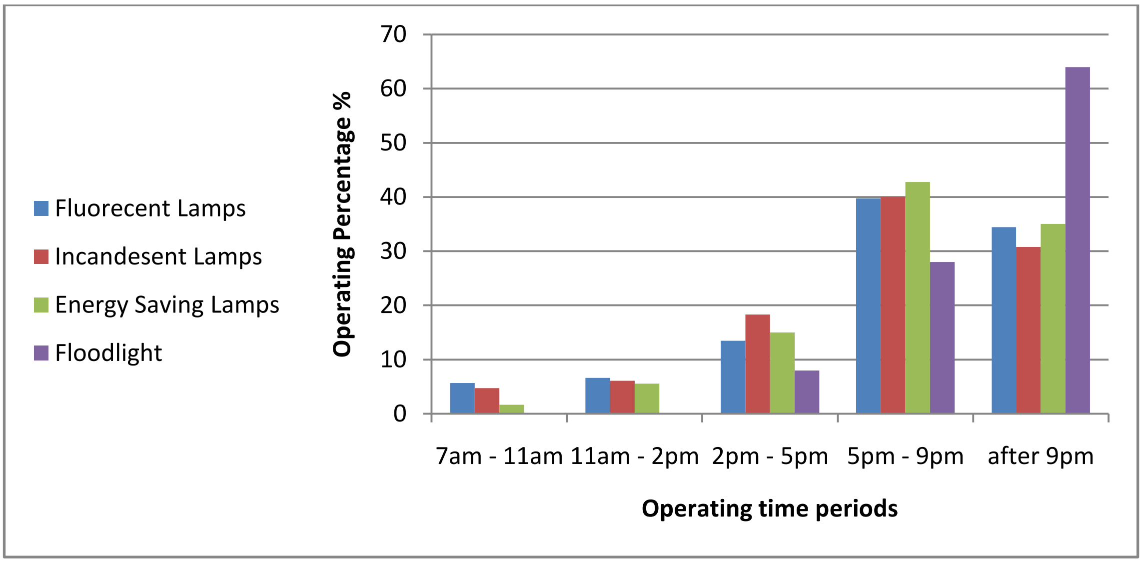

Figure (3.11) percentages of home lighting appliances operating intervals

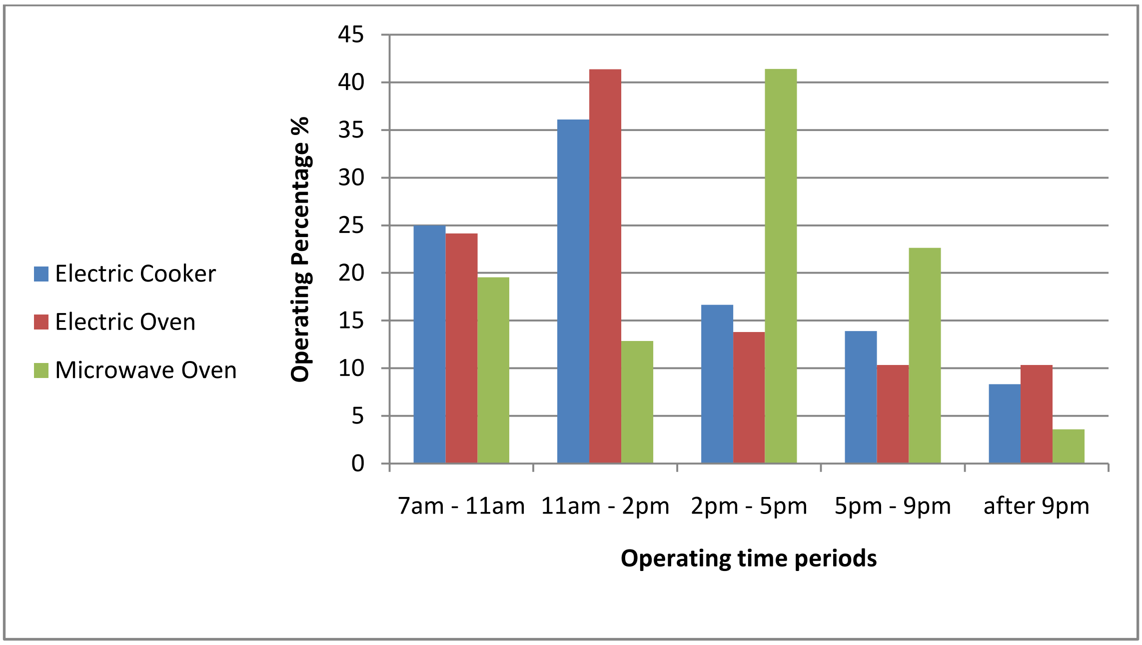

Figure (3.12) percentages of home cooking appliances operating intervals

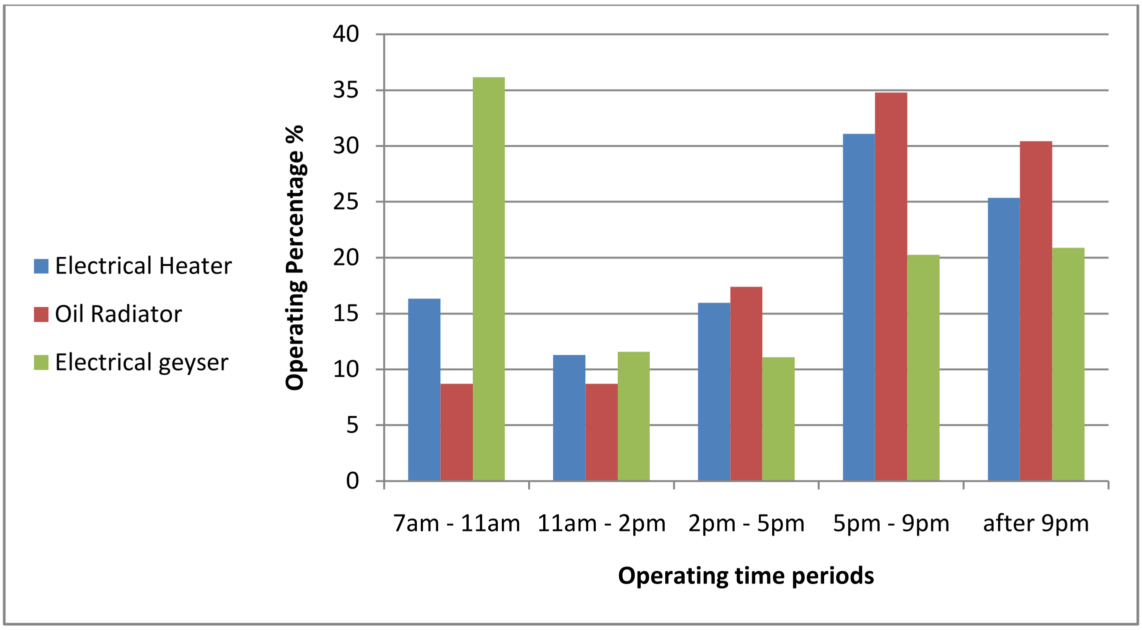

Figure (3.13) percentages of water and space heating appliances operating intervals

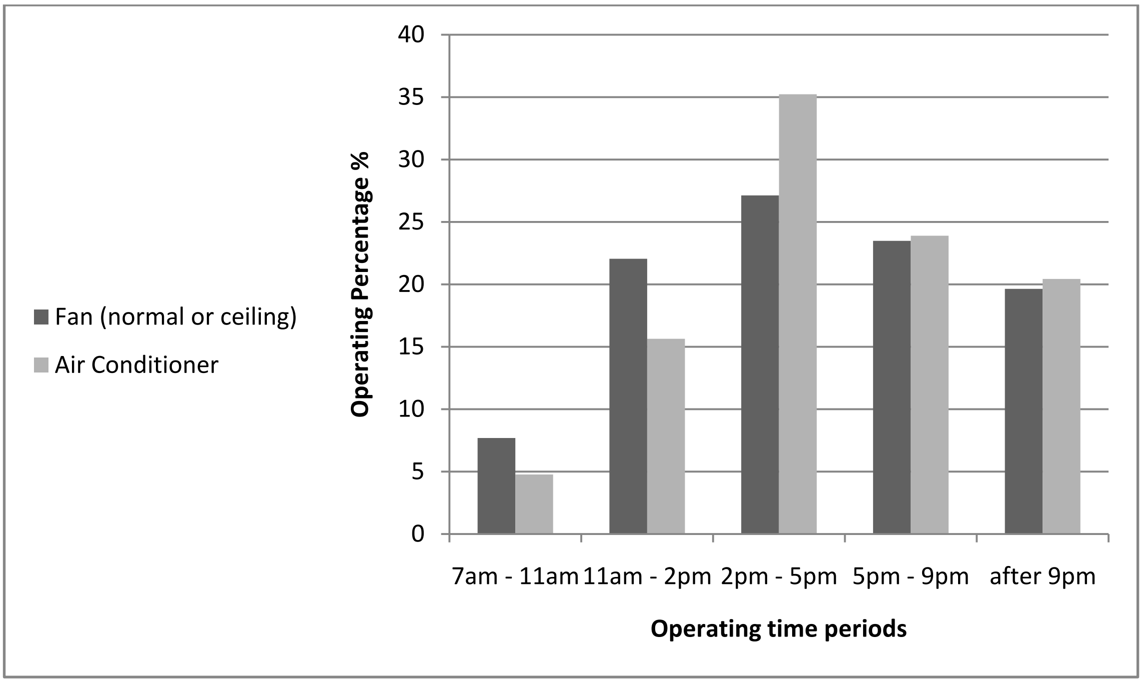

Figure (3.14) percentages of air conditioning appliances operating intervals

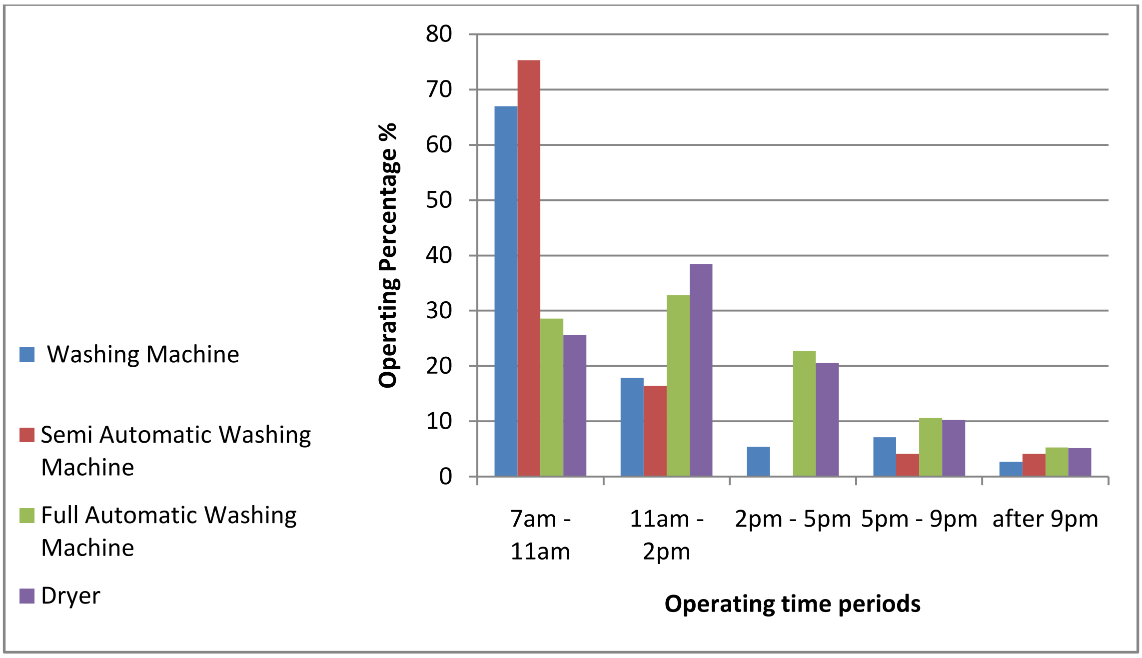

Figure (3.15) percentages of Laundry appliances operating intervals

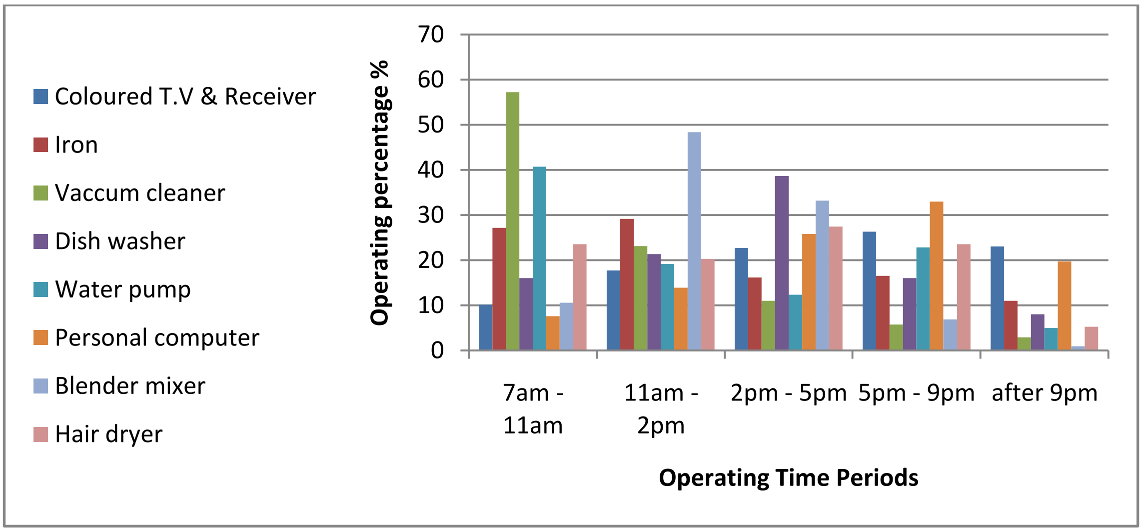

Figure (3.16) percentages of other home appliances operating intervals

3.3.4 Electrical power ratings and annual energy consumption of appliances:

The power rating of the appliances have been estimated from the survey questionnaire and the data sheets of many appliances brands used in Jordan.

Annual energy consumption is calculated using the following equation:

Annual energy consumption (KWh) = Appliance power rating (KW) × Annual utilization time (h)

For example, the rating of electrical water heater was assumed to be 1500 Watt, and from table (3.4), its annual utilization time is 1012.875h, hence the annual energy consumption will be = 1500Watt × 1012.875h

= 1519.3125 KWh/appliance

For cold appliances the annual energy consumption is estimated from the manufacturer's data sheets, since the annual utilization time for these appliances couldn’t be found through survey as mentioned before.

Table (3.6) summarizes the power rating and annual energy consumption of the surveyed appliances.

Table (3.6) power rating and annual energy consumption of domestic appliances

Appliances	Power rating Watt/appliance	Estimated Annual energy consumption KWh/appliance
Ordinary Washing Machine	280	31.171
Semi Automatic Washing Machine	580	76.212
Full Automatic Washing Machine	1100	264.99
Dryer	2000	142.35
Fan (normal or ceiling)	65	60.775
Air Conditioner	1400	1968.12
Electrical space Heater	1200	805.2
Oil Radiator	1500	915.75
Electrical water heater	1500	1519.3125
Electric Cooker	1200	713.94
Electric Oven	2000	660.65
Microwave Oven	1000	104.025
Fluorescent Lamps	32	86.9576
Incandescent Lamps	60	131.2905
Energy Saving Lamps	15	39.3105
Floodlight	250	456.70625
Colored T.V & Receiver	100	412.085
Iron	1000	89.425
Vacuum cleaner	1000	100.375
Dish washer	1000	346.75
Water pump	200	25.55
Personal computer	80	180.018
Blender mixer	300	14.7825
Hair dryer	800	74.46
Refrigerator less than 10 cuft	-	150*
Refrigerator (10-13) cuft	-	200*
Refrigerator (14-16) cuft	-	400*
Refrigerator larger than 16 cuft	-	550*
Freezer	-	450*
Water cooler	-	80*

* These values are estimated from manufacturer's data sheets and previous studies.

The total annual energy consumption for each appliance type can be found using the following equation:

Total energy consumption = Annual energy consumption (Table 3.6) × Ownership level (Table 3.2) × Total number of households.

Where the number of households having considerable amount of energy consumed is approximately 1098000 as provided by ERC.

For example:

Total annual energy consumption of hair dryers = 74.46 KWh × 0.79 × 1098000

= 64.588 GWh

Total annual energy consumption of Colored T.V & Receiver:

= 412.085 KWh × 1.25× 1098000

= 565.59 GWh

Total annual energy consumption and the sharing proportion of the total residential energy consumption for each appliance is shown in table (3.7). The total estimated Annual residential energy consumption is 6265 GWh. The breakdown of the residential energy consumption is shown in figure (3.17).

Comparing this result of 6265 GWh with that of 2009 which was 4888 GWh will show 28% increase. This can be explained due to the large increase in the load of air conditioning and fans during the exceptional hot summer.

Table (3.7) estimated total annual consumption of appliances in GWh

Appliances		Estimated total annual consumption GWh	Proportion of total residential consumption %	
			per appliance	per group
Laundry	Ordinary Washing Machine	7.529	0.12	3.61
	Semi Automatic Washing Machine	12.552	0.2	
	Full Automatic Washing Machine	194.942	3.11	
	Dryer	10.941	0.17	
Air conditioning	Fan (normal or ceiling)	126.788	2.02	13.06
	Air Conditioner	691.518	11.04	
Space Heating	Electrical space Heater	724.969	11.57	12.05
	Oil Radiator	30.164	0.48	
Water heating	Electrical water heater	1184.425	18.9	18.9
Cooking	Electric Cooker	31.356	0.5	2.72
	Electric Oven	72.539	1.16	
	Microwave Oven	66.247	1.06	
Lighting	Fluorescent Lamps	573.831*	9.16	22.26
	Incandescent Lamps	619.8748*	9.89	
	Energy Saving Lamps	165.745*	2.65	
	Floodlight	35.102*	0.56	
Other Appliances	Colored T.V & Receiver	565.586	9.03	17.26
	Iron	91.315	1.46	
	Vacuum cleaner	87.067	1.39	
	Dish washer	34.265	0.55	
	Water pump	8.696	0.14	
	Personal computer	217.425	3.47	
	Blender mixer	12.498	0.2	
	Hair dryer	64.588	1.03	
Food Reservation	Refrigerator less than 10 cuft	8.235	0.13	10.14
	Refrigerator (10-13) cuft	19.764	0.32	
	Refrigerator (14-16) cuft	215.208	3.43	
	Refrigerator larger than 16 cuft	253.638	4.05	
	Freezer	98.82	1.58	
	Water cooler	39.528	0.63	
Total		6265.167	100	100

* These values are larger little bit than the actual ones since here we assume all lights are operated.

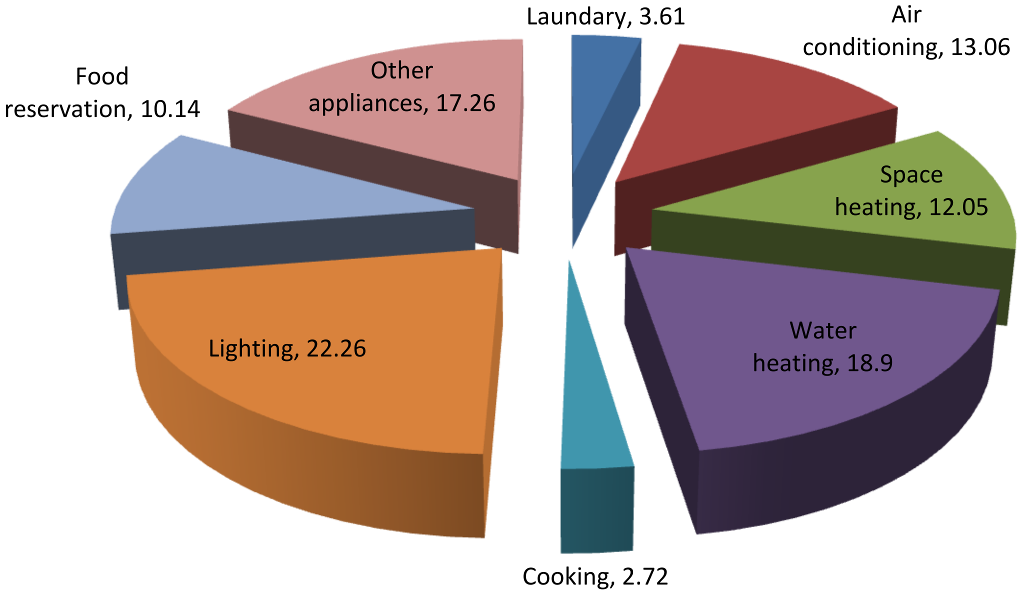

Figure (3.17) break down of residential energy consumption

3.4 Potential of DSM in Jordanian residential sector

As stated previously, the main objective of this thesis is to estimate the amount of load shifting in peaks of the daily load curve, by applying a proposed DSM on the residential sector.

Among the total surveyed appliances, DSM can be applied on the following appliances:

i. Laundry

ii. Electrical water heaters

iii. Iron

iv. Vacuum cleaner

v. Dish washing machine

vi. Water pump

3.4.1 Procedure of estimation

The following steps were applied in order to estimate load shifting by each appliance and then the total load shifting:

i. Find the annual energy consumption, E_y, from table (3.7). For example, laundry consumed 225.964 GWh/year.

ii. Evaluate the daily energy consumption, E_d. Where $E_d = E_y/365$

For laundry $E_d = 619.079$MWh/day

iii. Distribute E_d throughout the day by using the results of usage pattern from table (3.5). For example, ordinary washing machine has values of 7.529 GWh/year and 20.627 MWh/day of E_y and E_d respectively.

The distribution of E_d over the five time intervals will be as follows:

a. First interval = 66.96% × 20.627 MWh = 13.182 MWh

b. Second interval = 17.86% × 20.627 MWh = 3.684 MWh

c. Third interval = 5.36% × 20.627 MWh = 1.105 MWh

d. Forth interval = 7.14% × 20.627 MWh = 1.472 MWh

e. Fifth interval = 2.68% × 20.627 MWh = 0.553 MWh

By performing the same calculations for the other laundry appliances and summate them, the results were obtained shown in table (3.8)

Table (3.8) Distribution of daily laundry energy consumption in MWh

	7am - 11am	11am - 2pm	2pm - 5pm	5pm - 9pm	after 9pm
Energy consumption(MWh)	200	196.05	128.76	62.47	31.76

Tables(3.9 – 3.13) show the energy distribution for the other appliances(i.e. electrical water heater, iron, vacuum cleaner, dish washing machine and water pump)

Table (3.9) Distribution of the daily electrical water heater energy consumption in MWh

	7am - 11am	11am - 2pm	2pm - 5pm	5pm - 9pm	after 9pm
Energy consumption(MWh)	1173.72	375.77	359.87	657.44	678.21

Table (3.10) Distribution of daily electrical iron energy consumption in MWh

	7am - 11am	11am - 2pm	2pm - 5pm	5pm - 9pm	after 9pm
Energy consumption(MWh)	68	72.88	40.48	41.28	27.52

Table (3.11) Distribution of daily vacuum cleaner energy consumption in MWh

	7am - 11am	11am - 2pm	2pm - 5pm	5pm - 9pm	after 9pm
Energy consumption(MWh)	136.52	55.15	26.19	13.79	6.89

Table (3.12) Distribution of daily dish washing machines energy consumption in MWh

	7am - 11am	11am - 2pm	2pm - 5pm	5pm - 9pm	after 9pm
Energy consumption(MWh)	15.02	20.02	36.3	15.02	7.51

Table (3.13) Distribution of daily water pump energy consumption in MWh

	7am - 11am	11am - 2pm	2pm - 5pm	5pm - 9pm	after 9pm
Energy consumption(MWh)	9.71	4.56	2.94	5.44	1.18

iv. Evaluate the power consumed in each interval by using

$$P_i = \frac{E_i}{\tau_i} \quad \text{...} \quad (3.3)$$

Where: E_i: Energy consumed (MWh) in the i^{th} interval, τ_i

P_i : Power (MW) in the i^{th} interval, τ_i

Figure (3.18) shows the power distribution over all the intervals for the laundry appliances.

Figures (3.19 – 3.23) show the power distribution for the other appliances (i.e. electrical water heater, iron, vacuum cleaner, dish washing machine and water pump).

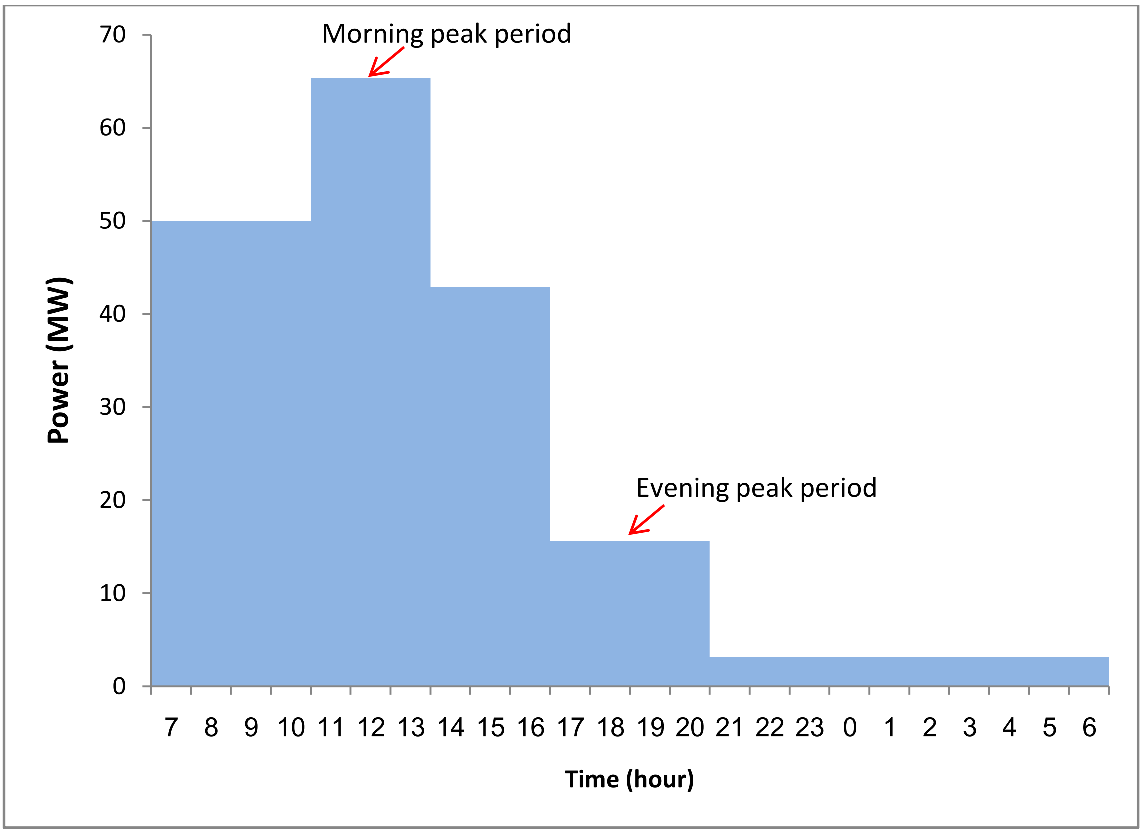

Figure (3.18) distribution of daily laundry daily power consumption in MW

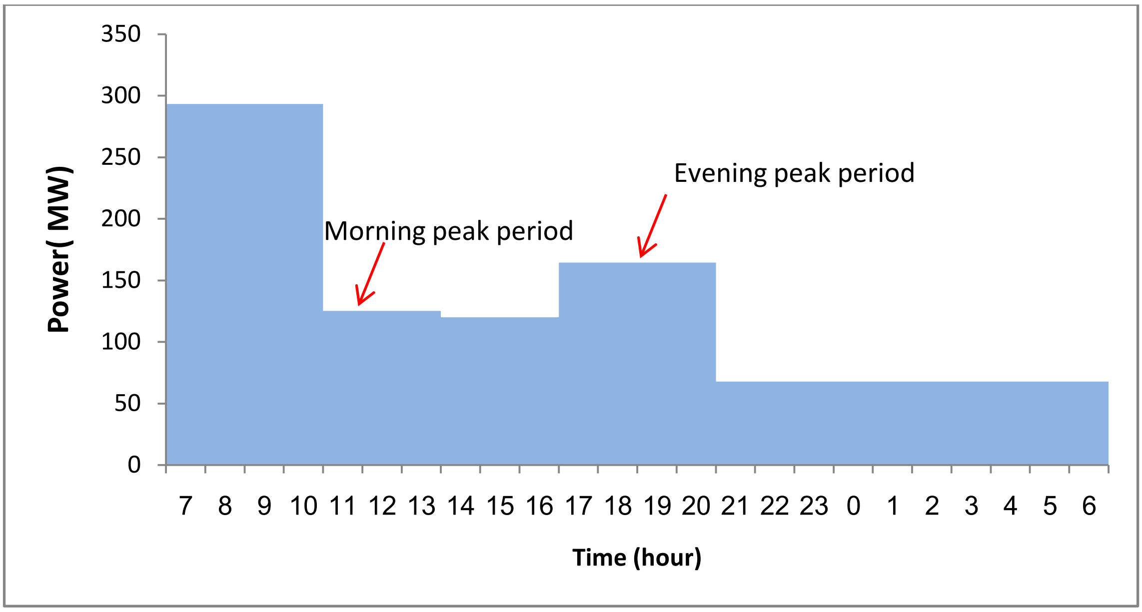

Figure (3.19) distribution of daily electrical water heater power consumption in MW

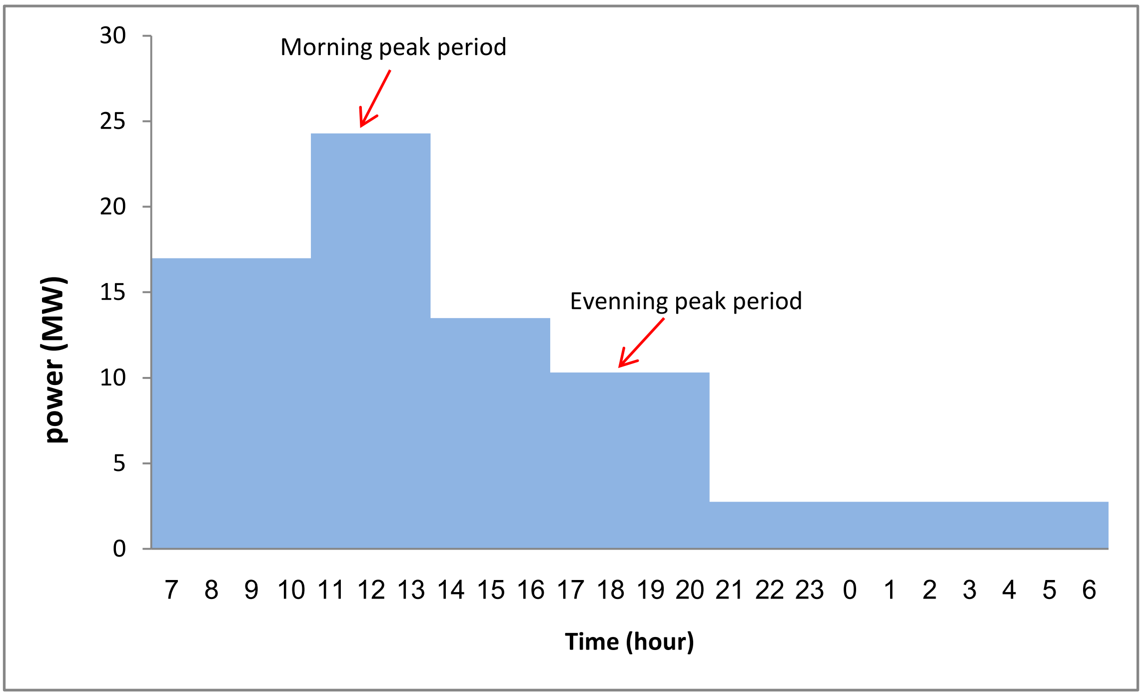

Figure (3.20) distribution of daily electrical iron power consumption in MW

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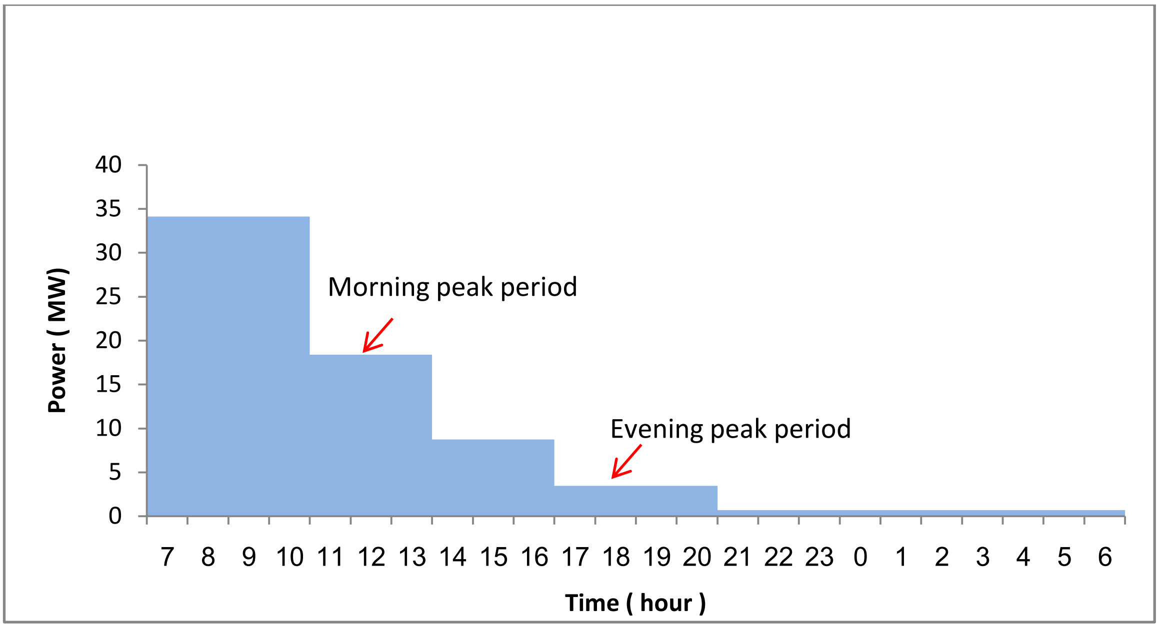

Figure (3.21) distribution of daily vacuum cleaner power consumption in MW

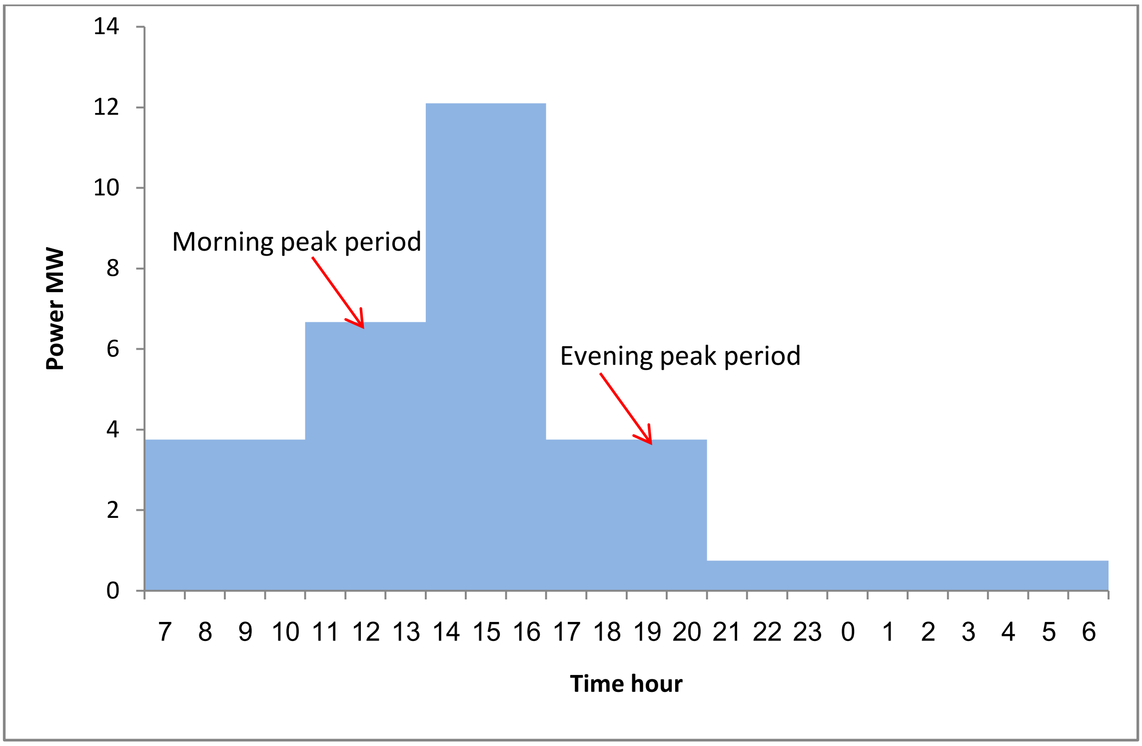

Figure (3.22) distribution of daily Dish washing machines power consumption in MW

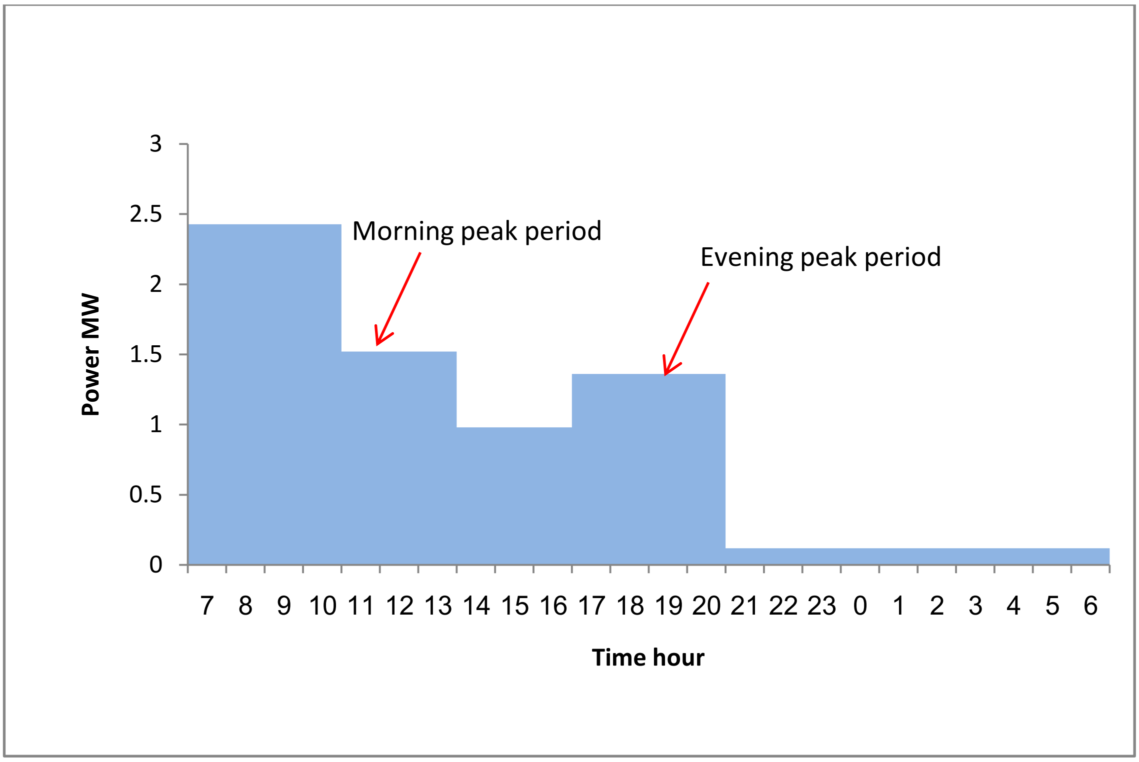

Figure (3.23) distribution of daily water pump power consumption in MW

v. Evaluate the energy and power which can be shifted from the peak periods (i.e. 11 am – 2 pm and 5 pm – 9 pm).

For example for the laundry appliances and from table (3.8) the morning peak energy is equal to 196.05 MWh. By assuming constant energy consumption over this interval, the corresponding power consumption is 65.35 MW (i.e. 196.05/3). Previous international studies (Fitzgerald and Sanders, 1998) found that 38% of domestic consumers are willing to shift their peak demand. Hence in the developed work a sensitivity analysis was performed through assumed three percentages: 25%, 38% and 50% of domestic consumers who are willing to shift their peak demand. The obtained results are shown in table (3.14).

Table (3.14) Peak power and amount of peak shift for various Percentages of domestic consumers percentage who are willing to shift their peak demand

Appliances	Peak power (MW)		Amount of peak shift (MW) for various percentages of domestic consumers who are willing to shift their peak demand					
	Morning	Evening	25%		38%		50%	
			Morning	Evening	Morning	Evening	Morning	Evening
Laundry	65.35	15.62	16.34	3.9	24.833	5.9356	32.675	7.81
Electrical water heater	125.26	164.36	31.31	41.09	47.5988	62.4568	62.63	82.18
Iron	24.29	10.32	6.07	2.58	9.2302	3.9216	12.145	5.16
Vacuum cleaner	18.38	3.45	4.6	0.86	6.9844	1.311	9.19	1.725
Dish washing machine	6.67	3.76	1.67	0.94	2.5346	1.4288	3.335	1.88
Water pump	1.52	1.36	0.38	0.34	0.5776	0.5168	0.76	0.68
Total	241.47	198.87	60.37	49.71	91.7586	75.5706	120.735	99.435

vi. Having estimated the individual contributions to peak shifts of the various appliances, the total power that can be shifted is evaluated by summing the individual contributions as shown in table (3.14). Figure (3.24) shows the total daily power consumption of the concerned appliances.

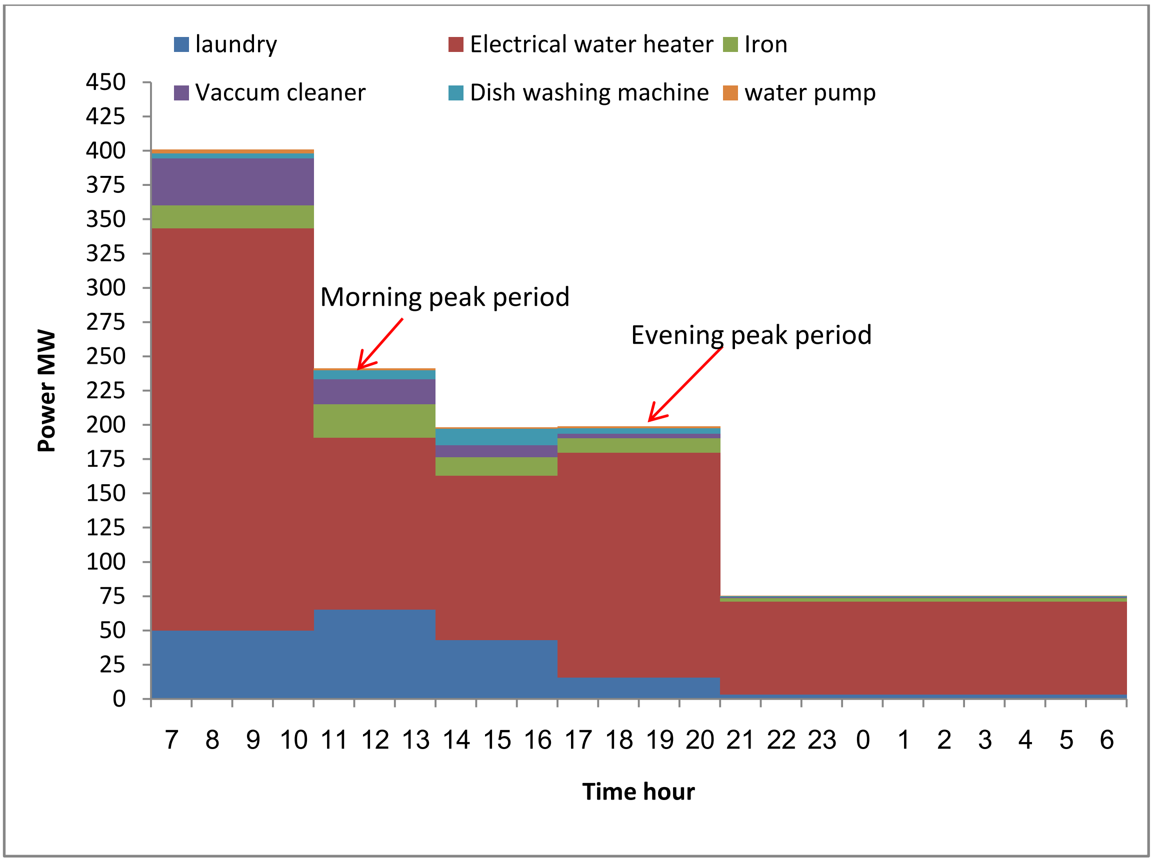

Figure (3.24) distribution of the daily total power consumption that can be shifted in MW

3.5 Modeling:

Chapter two explained the modeling techniques used in the residential sector. In Jordan top- down approach was the only used one, due to the lack of accurate dependable data about the household end-use consumption pattern.

Al- Ghandoor, et al., (2009) presented two empirical models developed for Jordanian residential sector based on multivariate linear regression analysis: Population, gross domestic product, weather conditions, fuel and electricity pricing are the factors taken into consideration in this model. NEPCO uses a top – down econometric approach to model the electrical energy consumption depending mainly on, population and electricity price.

In the developed work bottom- up approach was applied due to the obtained results of the annual energy consumption of each appliance type as explained in the previous sections and illustrated by the following equation:

$$E_t = \left[\sum_{i=1}^{i=n} O_i \times e_i\right] \times N_h \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (3.4)$$

Where:

E_t: Total annual residential sector electrical energy consumption.

O_i: Ownership level of appliance i ,appliance/house.

e_i: Annual energy consumption of appliance i.

N_h: Number of households .

n: Number of common appliances in each home.

Using this equation will yield the total amount found in table (3.7) which equals 6265.167 GWh.

3.6 Analysis and applications of peak shifting results

The advantages and applications of the estimated load shifting of 60.37MW (i.e. morning peak) and 49.71MW (i.e. evening peak) in Jordan can be summarized as follows:

1. It can defer the operation of the least efficient generating units. For example the 66MW and 33MW steam generating units (using heavy fuel oil) at Al-Hussien Thermal Power Station knowing that the average generation cost of these units are around 90 Fils/KWh whereas the cost of the most efficient generating units, such combined cycle units using gas, is around 35 Fils/KWh.

2. It can defer the commission of new power plants. For example the proposed IPP3 (i.e. the Third Independent Power Producer) consists of sets of 18MW diesel reciprocating generating units to be connected to the national grid at 400KV.
3. The previous two advantages can lead to the reduction in Air Pollution.
4. Load shifting can be applied through one or more of the followings:
    a) Time-of-use (TOU) tariffs where the utility provides incentives to the customer to shift loads from peak to off-peak by an appropriate tariff. Here in Jordan TOU tariff is applied on industrial sector who have installed load larger than 200KW. Also since January 2010 four star hotels and above and agricultural consumers who are connected to the network before that time have the right to choose this type of tariff whereas it is compulsory to the consumers who were connected to the network after that time. This approach could be extended to residential sector since the results showed that there is a potential for DSM on peak load shifting.
    b) Storage technologies, such as storage heater which stores thermal energy during the off-peak periods, and releases the heat when required during peak period.
    c) Outreach and Cooperation methods influence customer behavior and adoption by increasing customer awareness, knowledge and receipt of customized services.

3.7 Effects of restructuring on DSM in Jordan

Although Jordan imports 96% of its energy supplies from across its borders, but unfortunately DSM is not utilized efficiently in Jordan before and after restructuring. Which may be considered as an obstacle since countries who adopted DSM before restructuring favored its adoption after restructuring, since they have an experience in that.

Electricity distribution companies are key players in implementing DSM programs. Although the used ratemaking methodology for these companies decouples their profits from electricity sales, there is an underlying incentive to sell more electrical energy since their profit is measured as a percent of their investments and the reduction in sales penalizes the operational cash flow needed for their business. Hence there is disincentive for these companies to reduce their sales. Therefore this barrier should be removed through an attractive incentive mechanism to encourage distribution companies for implementing DSM. Such mechanism as mentioned in the previous chapter should involve cost recovery, lost revenue recovery and providing performance based incentives to these companies. The lack of consumers' funds to use it in buying new technology appliances regarding energy efficiency is another barrier for DSM in Jordan which can be removed by Energy Service Companies (ESCO) for large consumers as mentioned earlier in the previous chapter or by support these products by governments to reduce their costs for residential consumers.

For starting DSM programs in Jordan DSM should be a Service Obligation for electric Power Supply Companies as well as create incentives consistent with DSM objectives taking into account that DSM in the electricity sector will only happen with clear, strong, and consistent government and regulatory leadership. Therefore responsibility of

supervising DSM under the restructuring of the Jordanian electrical power system lie within ERC in cooperation with NEPCO (i.e. ISO). Regarding the funding of DSM programs can be obtained for example by introducing obligatory part in the tariff structure.

3.8Conclusion:

In this chapter the household end-use consumption pattern is obtained through a designed questionnaire and the results are compared with previous studies. Also these results are used to find the shared proportion of each appliance type in the total residential energy consumption to find the main drivers of the residential electrical energy consumption.

Bottom – up approach is adopted using the results of the survey to model the total electrical energy consumption of the residential sector.

The main contribution of this study is the introduction of the time of use of appliances in the conducted survey, which is used to plot the daily power consumption curves of household appliances through which load shifting feasibility for certain appliances is estimated.

CHAPTER 4

CONCLUSION

Restructured power systems are seeking alternatives to reduce the effects of shrinking reserve margins and financial risks of bulk expansion. DSM is becoming the best choice to mitigate these effects particularly for the countries, like Jordan, which can be used to manage their power-peak problems.

This thesis presents an approach of determining the potential of electrical load shifting in the residential sector, since it is the dominant sector in Jordan, based on collected data through a designed questionnaire, which concentrated on the time of using household appliances. The results showed that there is a potential for DSM by using peak load shifting.

The obtained results showed the significance of implementing DSM, especially when applied to other sectors. Consequently such results may help the ISO (NEPCO) in his decision for the unit commitment and generation expansion in the future.

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APPENDIX A

Questionnaire in Arabic language

الجـــامعة الأردنيـــة

كلية الدراسات العلـيا

الأخ الفاضل/ الأخت الفاضلة ...

تحية طيبة وبعد ،،،

تهدف هذه الاستبانة إلى دراسة أثر الأجهزة الكهربائية المنزلية على نمط الاستهلاك المنزلي للطاقة الكهربائية وذلك استكمالاً لموضوع إدارة الطلب على الطاقة الكهربائية في النظام الكهربائي معاد الهيكلة استكمالاً لمتطلبات الحصول على درجة الماجستير في إدارة الطاقة من الجامعة الأردنية.

يرجى من حضرتكم التكرم بالإجابة عن فقرات الإستبانة المرفقة، علماً بأن المعلومات التي ستقدمونها ستعامل بسرية تامة، ولن يتم استخدامها إلا لأغراض البحث العلمي فقط.

ولكم كل التقدير والاحترام

الباحث عامر الشديفات

- **كمية الاستهلاك الشهري (كيلو واط ساعة) كما هو مبيّن في فاتورة الكهرباء :-**
  - شتاءً (شهر كانون ثاني(1)): ....كيلو واط ساعة
  - صيفاً (شهر تموز (7)): ....كيلو واط ساعة

غرض الاستخدام	نوع الجهاز المستخدم	قدرة الجهاز بالكيلوواط أو الأمبير	عدد الأجهزة المستخدمة	عدد ساعات التشغيل اليومية		موعد التشغيل (الفترة من الساعة إلى الساعة)				
				صيفاً	شتاءً	7 صباحاً إلى 11 ظهراً	11 ظهراً إلى 2 بعد الظهر	2 بعد الظهر إلى 5 مساءاً	5 مساءاً إلى 9 ليلاً	ما بعد الساعة 9 ليلاً
التكييف	مكيف كهربائي									
	مروحة (سقف أو عادية)									
	أخرى (حددها)									
التدفئة	صوبة كهربائية شمعات									
	راديتر زيت									
الغسيل	غسالة عادية									
	غسالة نصف آلية									
	غسالة آلية									
	نشافة									
تسخين الماء	كيزر كهربائي									
الطهي	طباخ كهربائي									
	فرن كهربائي									
	ميكروويف									
	أخرى (حددها)									
الانارة	نيون									
	لمبات عادية									
	لمبات موفرة للطاقة									
	كشاف كهربائي									
	أخرى (حددها)									

غرض الاستخدام	نوع الجهاز المستخدم	قدرة الجهاز بالكيلوواط أو الأمبير	عدد الأجهزة المستخدمة	عدد ساعات التشغيل اليومية		موعد التشغيل (الفترة من الساعة إلى الساعة)				
				صيفاً	شتاءً	7 صباحاً إلى 11 ظهراً	11 ظهراً إلى 2 بعد الظهر	2 بعد الظهر إلى 5 مساءاً	5 مساءاً إلى 9 ليلاً	ما بعد الساعة 9 ليلاً
حفظ الأغذية	ثلاجة أقل من 10 قدم									
	ثلاجة (10-13) قدم									
	ثلاجة (14-16) قدم									
	ثلاجة اكبر من 16 قدم									
	فريز تجميد منفصل									
	مبرد ماء الشرب									
أجهزة أخرى	تلفزيون+ريسيفر									
	مكواة									
	مكنسة كهربائية									
	جلاية صحون									
	مضخة ماء كهربائية									
	جهاز حاسوب									
	خلاط									
	مجفف شعر (سشوار)									

APPENDIX B

Questionnaire in English language

University of Jordan
Faculty of Graduate Studies

Dear Respondents,

This survey aims to study "The effect of household appliances on the residential electrical energy consumption pattern ", in order to fulfill the requirements for the master's degree in Energy Management from the University of Jordan.

Kindly answer the clauses of this questionnaire, promising you that all the provided information will be treated in complete secrecy and will be used only for scientific research only.

Regards,

Amer Shdaifat

* Monthly consumption of electrical energy in KWh as recorded in monthly electrical bills:

- Winter (January): ……………………. KWh.

- Summer (July): ……………………....KWh.

Usage	Appliance type	Power rating	Number of used appliances	Daily operating period in hours		Time of usage (Time interval from hour to hour)				
				Winter	Summer	7am – 11am	11am – 2pm	2pm – 5pm	5pm – 9pm	After 9pm
Air conditioning	Air conditioner									
	Fan (any type)									
	Other(determine)									
Space heating	Electrical heater									
	Oil radiator									
Laundry	Ordinary washing machine									
	Semi automatic washing machine									
	Full automatic washing machine									
	Dryer									
Water heating	Electrical water heater									
Cooking	Electric Cooker									
	Electric Oven									
	Microwave Oven									
Lighting	Fluorescent Lamps									
	Incandescent Lamps									
	Energy Saving Lamps									
	Floodlight									

Usage	Appliance type	Power rating	Number of used appliances
Food Reservation	Refrigerator less than 10 cuft		
	Refrigerator (10-13) cuft		
	Refrigerator (14-16) cuft		
	Refrigerator larger than 16 cuft		
	Freezer		
	Water cooler		

Usage	Appliance type	Power rating	Number of used appliances	Daily operating period in hours		Time of usage (Time interval from hour to hour)				
				Winter	Summer	7am – 11am	11am – 2pm	2pm – 5pm	5pm – 9pm	After 9pm
Other Appliances	Colored T.V & Receiver									
	Iron									
	Vacuum cleaner									
	Dish washer									
	Water pump									
	Personal computer									
	Blender mixer									
	Hair dryer									

APPENDIX C

Statistical values of the conducted survey

Appliance	Ownership proportion %			Ownership level appliance/ house			Average daily utilization time in hours					
							Summer			Winter		
	$\bar{x}$	s	CI	$\bar{x}$	s	CI	$\bar{x}$	s	CI	$\bar{x}$	s	CI
Ordinary Washing Machine	21.48	0.411233	0.040761	0.22	0.434540	0.0430	0.34	0.171733	0.017022	0.27	0.1506	0.014927
Semi Automatic Washing Machine	0.15	0.360885	0.035771	0.15	0.360885	0.0357	0.39	0.298881	0.029625	0.33	0.213022	0.021115
Full Automatic Washing Machine	66.5	0.472609	0.046845	0.67	0.472608	0.0468	0.68	0.304666	0.030198	0.64	0.290738	0.028818
Dryer	6.65	0.259542	0.025726	0.07	0.259541	0.0257	0.11	0.099762	0.009888	0.28	0.082916	0.008219
Fan (normal or ceiling)	89.51	0.306765	0.030406	1.9	1.620459	0.1606	8.5	6.338387	0.664038	0	0	0
Air Conditioner	26.6	0.442422	0.043853	0.32	0.584843	0.0579	7.35	5.198849	0.515308	5.43	5.74546	0.569488
Electrical Heater	61.38	0.720907	0.071456	0.82	0.847685	0.0836	0	0	0	6.1	4.692137	0.593626
Oil Radiator	3.58	0.186043	0.0184	0.03	0.165564	0.0164	0	0	0	5.55	3.357488	0.332793
Electrical water heater	62.4	0.480043	0.047582	0.71	0.804008	0.0796	1.45	3.21101	0.318274	4.1	4.121101	0.408482
Electric Cooker	4.09	0.19836	0.019661	0.04	0.198360	0.0196	1.63	0.67082	0.066491	1.63	0.67082	0.066491
Electric Oven	9.46	0.293077	0.02905	0.1	0.295117	0.0292	0.92	0.382127	0.037876	0.89	0.336137	0.033318
Microwave Oven	57.54	0.494908	0.049055	0.58	0.504371	0.0499	0.3	0.248957	0.024677	0.27	0.244057	0.024191
Fluorescent Lamps	80.31	0.398189	0.039468	6.01	6.317245	0.6261	7.08	4.475141	0.443574	7.81	4.310081	0.427214
Incandescent Lamps	57.29	0.495292	0.049093	4.3	7.263252	0.7199	5.85	4.319764	0.428173	6.14	4.125147	0.408883
Energy Saving Lamps	46.8	0.499616	0.049522	3.84	5.941779	0.5889	6.85	4.987842	0.494393	7.51	4.56116	0.452101
Floodlight	4.09	0.19836	0.019661	0.07	0.354948	0.0351	5.31	2.24258	0.222284	4.7	1.946507	0.192937
Colored T.V & Receiver	99.49	0.071428	0.00708	1.25	0.714950	0.0708	11.23	5.676277	5.676277	11.35	5.193616	0.514789

Iron	85.17	0.35589	0.035276	0.93	0.469574	0.0465	0.27	0.188377	0.018672	0.22	0.178667	0.017709
Vacuum cleaner	74.42	0.436843	0.0433	0.79	0.508398	0.0503	0.3	0.237346	0.023526	0.25	0.189207	0.018754
Dish washer	8.7	0.282132	0.027965	0.09	0.294683	0.0292	0.97	0.126854	0.012574	0.93	0.172873	0.017135
Water pump	29.16	0.455063	0.045106	0.31	0.512177	0.0507	0.48	0.471008	0.046686	0.22	0.283427	0.028093
Personal computer	77.75	0.416462	0.04128	1.1	0.852011	0.0844	6.1	8.312723	0.823954	6.23	5.006245	0.496217
Blender mixer	65.47	0.476065	0.047187	0.77	0.781508	0.0774	0.15	0.091446	0.009064	0.12	0.090643	0.008985
Hair dryer	65.47	0.476065	0.047187	0.79	0.711410	0.0705	0.31	0.207012	0.020519	0.2	0.171131	0.016962
Refrigerator less than 10 cuft	4.09	0.19836	0.019661	0.05	0.226889	0.0224						
Refrigerator (10-13) cuft	9.21	0.289497	0.028695	0.09	0.289497	0.0286						
Refrigerator (14-16) cuft	46.04	0.499065	0.049467	0.49	0.55400	0.0549						
Refrigerator larger than 16 cuft	41.43	0.493236	0.048889	0.42	0.515215	0.0510						
Freezer	18.67	0.39017	0.038674	0.2	0.423163	0.0419						
Water cooler	42.46	0.494908	0.049055	0.45	0.537247	0.0532						

$\bar{x}$: Average S: Standard deviation of the sample. CI: Confidence interval

أدارة الطلب على الطاقة الكهربائية في النظام معاد الهيكلة

إعداد
عامر عودة عبدالله الشديفات

المشرف
الاستاذ الدكتور ضيف الله الدلابيح

الملخص

نتيجة للتحديات التي تواجهها أنظمة القدرة الكهربائية وبالأخص بعد اعادة هيكلتها والتي تتمثل في نقص الاحتياط للقدرة التوليدية والمخاطر المالية الناتجة عن توسعة الشبكات الكهربائية وبناء محطات توليد جديدة فإن ادارة الطلب على الطاقة الكهربائية اصبحت ضرورة ملحّة، لذلك تم القيام بدراسة مسحية للقطاع المنزلي في الأردن لتحديد نمط الاستهلاك المنزلي للطاقة الكهربائية. حيث استخدمت نتائج المسح لإيجاد امكانية نقل بعض الاحمال التي يمكن نقلها الى خارج اوقات الذروة كوسيلة من وسائل ادارة الطلب على الطاقة الكهربائية . حيث وجد بالامكان على اقل تقدير نقل مامقداره 60 ميغا واط من فترة الذروة الصباحية و 49 ميغا واط من فترة الذروة المسائية.